TRANSACTIONS

The American Fisheries Society

1937

SIXTY-SEVENTH ANNUAL MEETING

MEXICO CITY, MEXICO

AUGUST 23, 24 and 25, 1937

Transactions

of the

American Fisheries Society

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MEXICO CITY, MEXICO

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Published Annually by the Society

Washington, D. C.

1938

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THE AMERICAN FISHERIES SOCIETY

Organized 1870 **Incorporated 1910**

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fisheries problems.

OFFICERS FOR 1936-1937

President................A. G. HUNTSMAN, Toronto, Canada
1st Vice-President................I. T. QUINN, Montgomery, Alabama
2nd Vice-President................FRED J. FOSTER, Seattle, Wash.
Secretary-Treasurer................SETH GORDON, Harrisburg, Pa.
Address all routine mail to the Secretary, Investment Bldg., Washington, D. C.
Librarian................KENNETH E. COBB, Windsor Locks, Conn.

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President................I. T. QUINN, Montgomery, Alabama
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Fish Culture................JOE HOGAN, Lonoke, Ark.
Aquatic Biology and Physics................EUGENE SURBER, Leetown, W. Va.
Commercial Fishing................LESTER SMITH, Port Washington, Wis.
Protection and Legislation................B. M. BRENNAN, Seattle, Wash.
Angling................JAMES BROWN, Frankfort, Ky.

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*For street addresses see membership list.

STANDING COMMITTEES, 1937-1938

Executive Committee

The Executive Committee consists of the president, vice-presidents, secretary, librarian, divisional vice-presidents, and A. G. Huntsman, the president last year.

Committee on Foreign Relations

James A. Rodd, *Chairman*	Ottawa, Canada
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Arthur L. Clark	Hartford, Conn.
W. F. Thompson	Seattle, Wash.
Wm. J. Tucker	Austin, Texas
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Senor Juan Zinser	Mexico City, Mex.

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Carl L. Hubbs, *Chairman*	Ann Arbor, Mich.
Walter H. Chute	Chicago, Ill.
Wm. J. K. Harkness	Toronto, Canada
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Fred J. Foster	Seattle, Wash.
Charles A. French	Ellwood City, Pa.
Seth Gordon	Harrisburg, Pa.
Wm. J. K. Harkness	Toronto, Canada
A. S. Hazzard	Ann Arbor, Mich.
Carl L. Hubbs	Ann Arbor, Mich.
A. G. Huntsman	Toronto, Canada
S. B. Locke	Chicago, Ill.
James A. Rodd	Ottawa, Canada
John Van Oosten	Ann Arbor, Mich.
Geo. C. Warren, Jr.	Summit, N. J.

Committee on Pollution Study

Harry B. Hawes, *Hon. Chairman*	Washington, D. C.
M. M. Ellis, *Chairman*	Columbia, Mo.
Talbott Denmead, *Secretary*	Washington, D. C.
Milton P. Adams	East Lansing, Mich.
C. M. Baker	Madison, Wis.
Charles A. French	Ellwood City, Pa.
Grover C. Ladner	Philadelphia, Pa.
S. B. Locke	Chicago, Ill.
M. D'Arcy Magee	Washington, D. C.
C. C. Regan	Covington, Ky.
Kenneth A. Reid	Connellsville, Pa.
James A. Rodd	Ottawa, Canada
Carl D. Shoemaker	Washington, D. C.
W. F. Thompson	Seattle, Wash.
John Van Oosten	Ann Arbor, Mich.
Henry B. Ward	Urbana, Ill.

PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift	1870-1872	New York, N. Y.
2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877*	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt	1881-1882	New York, N. Y.
12.	George Shepard Page	1882-1883	New York, N. Y.
13.	James Benkard	1883-1884	New York, N. Y.
14.	Theodore Lyman	1884-1885	Washington, D. C.
15.	Marshall McDonald	1885-1886	Washington, D. C.
16.	W. M. Hudson	1886-1887	Chicago, Ill.
17.	William L. May	1887-1888	Washington, D. C.
18.	John Bissell	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891-1892	Washington, D. C.
22.	Herschel Whitaker	1892-1893	New York, N. Y.
23.	Henry C. Ford	1893-1894	Chicago, Ill.
24.	William L. May	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington	1895-1896	New York, N. Y.
26.	Herschel Whitaker	1896-1897	New York, N. Y.
27.	William L. May	1897-1898	Detroit, Mich.
28.	George F. Peabody	1898-1899	Omaha, Nebr.
29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.
35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va.

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

36.	E. A. Birge	1906-1907	Grand Rapids, Mich.
37.	Hugh M. Smith	1907-1908	Erie, Pa.
38.	Tarleton H. Bean	1908-1909	Washington, D. C.
39.	Seymour Bower	1909-1910	Toledo, Ohio
40.	William E. Meehan	1910-1911	New York, N. Y.
41.	S. F. Fullerton	1911-1912	St. Louis, Mo.
42.	Charles H. Townsend	1912-1913	Denver, Colo.
43.	Henry B. Ward	1913-1914	Boston, Mass.
44.	Daniel B. Fearing	1914-1915	Washington, D. C.
45.	Jacob Reighard	1915-1916	San Francisco, Calif.
46.	George W. Field	1916-1917	New Orleans, La.
47.	Henry O'Malley	1917-1918	St. Paul, Minn.
48.	M. L. Alexander	1918-1919	New York, N. Y.
49.	Carlos Avery	1919-1920	Louisville, Ky.
50.	Nathan R. Buller	1920-1921	Ottawa, Canada
51.	William E. Barber	1921-1922	Allentown, Pa.
52.	Glen C. Leach	1922-1923	Madison, Wis.
53.	George C. Embody	1923-1924	St. Louis, Mo.
54.	Eben W. Cobb	1924-1925	Quebec, Canada
55.	Charles O. Hayford	1925-1926	Denver, Colo.
56.	John W. Titcomb	1926-1927	Mobile, Ala.
57.	Emmeline Moore	1927-1928	Hartford, Conn.
58.	C. F. Culler	1928-1929	Seattle, Wash.
59.	David L. Belding	1929-1930	Minneapolis, Minn.
60.	E. Lee LeCompte	1930-1931	Toronto, Canada
61.	James A. Rodd	1931-1932	Hot Springs, Arkansas
62.	H. S. Davis	1932-1933	Baltimore, Md.
63.	Fred A. Westerman	1933-1934	Columbus, Ohio
64.	E. L. Wickliff	1934-1935	Montreal, Canada
65.	Frank T. Bell	1935-1936	Tulsa, Oklahoma
66.	A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67.	I. T. Quinn	1937-1938	Mexico City, Mexico

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APPENDIX

PART I
BUSINESS SESSIONS

TRANSACTIONS

of the 67th Annual Meeting of the AMERICAN FISHERIES SOCIETY

MEXICO CITY, MEXICO

AUGUST 23, 24 and 25, 1937

The 67th Annual Meeting of the American Fisheries Society convened at 10:00 A. M., August 23, 1937, in the Palace of Fine Arts, Mexico City, Mexico, the President, Dr. A. G. Huntsman of Toronto, Canada, presiding.

The meetings were held in cooperation with the 31st Annual Convention of the International Association of Game, Fish and Conservation Commissioners.

The registered attendance of members, delegates, and guests was as follows:

Registered Members in Attendance*

Aldrich A. D., Tulsa, Okla.

Bell, Frank T., Washington, D. C.
Blizzard, Logan, McGregor, Iowa (Rep. Fish and Game Dept.)
Brennan, B. M., Seattle, Wash.

Cahalane, Victor H., Washington, D. C.
Chalk, John D., Raleigh, N. C. (Rep. Div. Game and Inland Fisheries)
Chute, Walter, Chicago, Ill.
Clark, Arthur L., Hartford, Conn.

Dauenhauer, J. B., Jr., New Orleans, La. (Rep. Louisiana Dept. of Conservation.)
Davis, H. C., San Francisco, Calif. (Rep. Div. of Fish and Game.)
Dellinger, S. C., Fayetteville, Ark.
Denmead, Talbott, Baltimore, Md.
Donaldson, L. R., Seattle, Wash.
Donaldson, Paul D., Seattle, Wash.

Ellis, M. M., Columbia, Mo.

Foster, Fred J., Seattle, Wash.

Gordon, Seth, Harrisburg, Pa.
Graves, D. N., Little Rock, Ark.
Gutermuth, C. R., Indianapolis, Ind.

Hoffmaster, P. J., Lansing, Mich.
Hogan, Joe, Lonoke, Ark.
Holland, Ray P., New York, N. Y.
Huntsman, A. G., Toronto, Ontario, Canada

Ivankovich, George, San Pedro, Calif. (Rep. Deep Sea and Purse Seine Fishermen's Union of Calif.)

James, M. C., Washington, D. C.

Langlois, T. H., Columbus, Ohio
Leach, G. C., Washington, D. C.
Loutit, W. H., Grand Haven, Mich.
Lynch, J. E., Seattle, Wash.

Madsen, David H., Salt Lake City, Utah
Miles, Lee, Little Rock, Ark.

O'Connell, Frank, Lincoln, Neb. (Rep. Neb. Game, Forestation and Parks Com.)

Pautzke, C. F., Seattle, Wash.

Quinn, I. T., Montgomery, Ala.

Reid, Kenneth A., Connellsville, Pa.

Seale, A., San Francisco, Calif.
Shawhan, H. W., Charleston, W. Va. (Rep. W. Va. Conservation Com.)
Shelford, V. E., Urbana, Ill.
Shoemaker, Carl D., Washington, D. C.
Smith, Lester, Port Washington, Wis.
Solis, Samuel, Veracruz, Mexico
Sykes, C. E., Ardmore, Okla. (Rep. Oklahoma Game and Fish Com.)

Tarzwell, Clarence M., Albuquerque, N. Mex.
Tucker, William J., Austin, Tex.

Van Oosten, John, Ann Arbor, Mich.
Vladykov, Vadim D., Baltimore, Md.

Walker, C. H., Natchitoches, La.
Westerman, Fred A., Lansing, Mich.

Young, F. S., Chicago, Ill.

Zinser, Juan, Mexico City. Mex.

Registered Visitors in Attendance*

Aldrich, Mrs. A. D., Tulsa, Okla.
Alexander, W. L., Dallas, Tex.
Anderson, Brooke, Chicago, Ill.
Anderson, George, San Francisco, Calif.

Barker, Elliott S., Santa Fe, N. Mex.
Barker, Mrs. Elliott S., Santa Fe, N. Mex.
Bell, Allie C., Washington, D. C.
Berriozabal, Felipe B., Mexico City, Mex.
Birch, R. F., Jr., Atlanta, Ga.
Brewster, Sam F., Nashville, Tenn.
Bruce, Mrs., New York, N. Y.
Burgos, Felipe Ing., Mexico City, Mex.

Cardenas Lic. C., Mexico City, Mex.
Carrillo, Roberto Arroyo, Lake Don Martin, Mexico
Chute, Mrs. Walter, Chicago, Ill.
Corn, Eugenia, Lonoke, Ark.
Corn, Margaret, Lonoke, Ark.

Davis, Hugh S., Tulsa, Okla.
Davis, Mrs. Herbert C., San Francisco, Calif.
deLearn, Mrs. S. M., Laredo, Tex.
Donaldson, Mrs. L. R., Seattle, Wash.

Espinosa, Gilbert, Santa Fe, N. Mex.
Espinosa, Mrs. Gilbert, Santa Fe, N. Mex.
Espinosa, Lic. Pedro Molina, Mexico City, Mex.

Fragoso, Fco. Navarro, Mexico City, Mex.
Fuller, A. C., Natchitoches, La.

Gabrielson, I. N., Washington, D. C.
Garrett, Broox C., Shreveport, La.
Gilchrist, Don A., Albuquerque, N. Mex.
Gordon, Mrs. Seth, Harrisburg, Pa.
Gordon, Phyllis, Harrisburg, Pa.
Graves, Mrs. D. N., Little Rock, Ark.
Gutermuth, Mrs. C. R., Indianapolis, Ind.

Herrera, Fco., Mexico City, Mex.
Hickie, Paul, Lansing, Mich.
Hitzfelder, A. E., San Antonio, Tex.
Hogan, Mrs. Joe, Lonoke, Ark.
Hogan, W. Murray, Nashville, Tenn.
Holland, Mrs. Ray P., New York, N. Y.
Huddleson, Lee, Lincoln, Nebr.

Johnson, Uncas, Austin, Tex.

Langlois, Mrs. T. H., Columbus, Ohio
la Llave, Jose de, Mexico City, Mex.
Lincoln, F. C., Washington, D. C.
Logsdon, J. W., Tulsa, Okla.
Loutit, Mrs. W. H., Grand Haven, Mich.
Lyttle, R. G., Denver, Colo.
Lyttle, Mrs. R. G., Denver, Colo.

Madsen, Mrs. D. H., Salt Lake City, Utah.
McCullough, E. B., Monticello, Ark.
McMahan, Boyd, Altus, Okla.
McMahan, James W., Okemah, Okla.
Markovich, John, San Pedro, Calif.
Mendez, S. Rodriquez, Mexico City, Mex.
Morales, Ma. Alicia, Laredo, Tex.
More, Jake, Atlanta, Ga.
Munoz, Ing. J. R., Mexico City, Mex.
Murphy, Alberto Alvarez, Mexico City, Mex.

Pautler, G. P., Tulsa, Okla.
Pautzke, Mrs. Clarence, Seattle, Wash.
Pearson, T. Gilbert, New York, N. Y.
Peck, Hal C., Amarillo, Tex.
Peck, Mrs. Hal C., Amarillo, Tex.
Phillips, Johnson, Midland, Tex.
Phillips, Mrs. Johnson, Midland, Tex.
Pollard, H. S., Austin, Tex.
Prieto, Eduardo, Mexico City, Mex.

Quinn, Mrs. I. T., Montgomery, Ala.
Quinn, I. T., Jr., Montgomery, Ala.

Richil, Paul, Lansing, Mich.
Rickey, L. D., Ardmore, Okla.
Roult, T., Jr., San Antonio, Tex.
Rudisel, C. R., Austin, Tex.
Ruhl, H. D., Lansing, Mich.
Ruiz, Horacio, Mexico City, Mex.

Schwabe, John, Tulsa, Okla.
Scott, Walter, Houston, Tex.
Segura, R., Mexico City, Mex.
Shelford, Mrs. Victor E., Champaign, Ill.
Smith, Mrs. Lester, Port Washington, Wis.
Snow, Robert, Austin, Tex.
Sullivan, M. M., Spaulding, Neb.

Tacker, Juan A., C. Juarez, Mex.
Tarzwell, Mrs. Clarence M., Albuquerque, N. Mex.
Taylor, H. T., Tulsa, Okla.
Thomae, Adalberto C., P. Negras, Coah.
Thomas, W. H., Natchitoches, La.
Torres, Jose, Sonora, Sin.
Trevino, Juan F., Chihuahua, Mex.
Tucker, Mrs. Wm. J., Austin, Texas
Turner, K. D., Oklahoma City, Okla.

Van Coevering, Jack, Detroit, Mich.
Van Coevering, Mrs. Jack, Detroit, Mich.
Villasenor, Fernando, Empacadoras, Mexico.

Wakefield, S. A., Shelbyville, Ky.
Walker, Mrs. C. H., Natchitoches, La.
White, Flossie, Washington, D. C.

Young, Mrs. Floyd S., Chicago, Ill.

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*A number of other visitors registered their names but failed to supply addresses. Some of those listed as visitors probably represented state or club members, but failed to so identify themselves when registering.

OPENING ADDRESSES

PRESIDENT HUNTSMAN: In opening this joint session of the American Fisheries Society and the International Association of Game, Fish and Conservation Commissioners I wish to express our great appreciation for the very kind courtesies of the several Government officials. It is indeed a very great pleasure for us to be here, and our only regret is that the time has been so long delayed.

We are very pleased, indeed, to see our American Fisheries Society become, in this way, so distinguished as the North American Fisheries Society. In the past it has met in various parts of the United States and Canada, but it has extended the scope of its activities to the major portion of the North American Continent so that now our society is truly composed of representatives of three nations. I hope that in the future, contributions made by Mexico to these activities will be of high value.

I wish to now present Sr. Juan Zinser, of the Department of Forestry, Game and Fisheries of the Republic of Mexico.

SENOR ZINSER: It is a real great source of satisfaction for me to have you here at this conference. We think it a great honor, especially for me, to have this conference brought to Mexico City. As you go back and see our friends in the States tell them we are thinking of all of them, and we would like to have them visit us here in this country.

We have here in Mexico, as you will see, a great country with great natural resources. Now we are working for the conservation of them. Our President is a great lover of nature, and he is working hard for the conservation of these resources. But he is not here as he is on a trip to Ucatan, but I will now introduce to you his Secretary, Senor Salvador Guerrero, Secretary General of the Department of Forestry, Game and Fisheries, who, in the name of Gen. Lazaro Cardenas, President of the Republic, will greet you.

SENOR GUERRERO: The 67th Annual Convention of the American Fisheries Society, and the 31st Annual Convention of the International Association of Game, Fish and Conservation Commissioners, which Conventions have honored Mexico by choosing its capital as their seat, afford me the opportunity to extend you, in the name of Gen. Lazaro Cardenas, President of the Republic, a hearty welcome to Mexico, which receives you with open arms.

The number of annual meetings held by the International Association of Game, Fish and Conservation Commissioners, as well as by the American Fisheries Society, clearly indicated how long has been the existence of these Societies, which are the highest exponents of the culture of the United States of America and of the Dominion of Canada. These two countries have distinguished themselves by the protection they give Nature, for they have established game reservations or shelters and National Parks wherein fauna and flora are held sacred, because there, at the National Parks, no harm may be done any birds, nor may a stroke of the axe fall on any tree, and the waters follow their natural course. These two countries, as I say, are those that have done most for nature protection, and to them goes out a brotherly greeting from Mexico, so that the members of these Conventions who honor us with their visit, both American and Canadian, may carry to those countries Mexico's greeting. The President of the Republic, General Lazaro Cardenas, and the Chief of the Department of Forestry, Game and Fisheries, Engr. Miguel A. de Quevedo, wish you, members of the Convention, an enjoyable sojourn among us, and that you may find in Mexico a propitious field for study and research. [Applause.]

Senor Zinser: I now bring you a greeting from Engr. Miguel A. de Quevedo, Chief of the Department of Forestry, Game and Fisheries, which reads as follows:

"It is a source of keen satisfaction to the Government of Mexico, and more especially to the Department of Forestry, Game and Fisheries, that this Convention should be held in the City of Mexico for the first time in its history. This is no doubt due to a realization, by those interested, of the great attention being devoted by our present Government to the important branch of Conservation of the Natural Resources of our Territory, and of its Maritime and Inland Waters. To this end the Administration has instituted this new organ, the Autonomous Department of Forestry, Game and Fisheries, thus not only carrying out the Resolutions contained in the Government's own Six-Year Plan, but also those other Resolutions adopted at the celebrated Conference on Conservation of the Natural Resources of North America, held in response to an invitation from President Theodore Roosevelt, in February, 1909, at the City of Washington. The great honor devolved upon me of attending that Convention as Delegate from Mexico, specially charged with the duty of dealing with matters connected with the resources of our forests and wildlife.

"The divers vicissitudes through which Mexico happened to pass just when that momentous action for Conservation of Natural Resources began, pursuant to the Resolutions adopted at the Conference in question, on the drafting of which I cooperated with the pioneer of the movement in the United States, Hon. Gifford Pinchot, hindered immediate application of same in our country, while in your two nations the movement in question grew apace, Bureaus of Conservation having been established in all the States of the Union, this implying recognition of the fact that the drive for Conservation of Natural Resources meant conservation of the Nation itself, a truth that was abundantly brought out by us at that celebrated Conference. From it followed also, beyond all doubt, the advancement of your two great societies that today afford us keen satisfaction by assembling in Mexico's Capital. They have, besides, extended to us invitations to attend their meetings and debates on the most desirable measures to be mutually adopted for protection of resources so valuable as are game and fisheries; for wildlife, with scant respect for international boundaries, goes hither and thither from one nation to another, setting us humans a splendid example of mutual migratory cordiality, as it journeys in caravans keenly alive to the common interest and abounding in good will, symbolical of peace and the strengthening of loyal friendship throughout the Americas, under the banner of Nature Protection.

"So that, my dear fellow-members of these Conventions, we welcome you to Mexico, for here both Government and people receive you with sincere pleasure and desire that your stay among us may prove most pleasant in every way." [Applause.]

(Greetings also were presented from the Dominion of Canada, the United States of America, and other countries, by official representatives.)

President Huntsman: We appreciate these messages of greeting and goodwill, also the fine work of the Committee on Local Arrangements, headed by Senor Zinser. The time has now come to plunge into the program before us.

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

For the Year 1936-1937

SETH GORDON

The report I have to present this year is not as encouraging as I should like. The membership curve of the Society, instead of showing a considerable gain in new members, shows a downward tendency. Last year we added 123 new members to our rolls, while this year only 105 were added, comprising the following classes: ninety-four active, one dealer, one state and nine libraries.

Now let us compare our losses for the two years. Last year through resignation, non-payment of dues and death we dropped ninety-seven members. Due to the change in the Constitution and By-laws regarding carrying inactive members, it was necessary to drop a large number of members for non-payment of dues whom we had carried hoping eventually they would pay up and become active again. But this year we do not have that excuse, yet our loss is exactly the same, ninety-seven members. This year we dropped for non-payment of dues eighty former active members, four clubs and dealers, and one state, a total of eighty-five. Through resignation we lost four active and one library, and by death seven of our members. The net gain for the year 1936-1937 is only eight members, while for the previous period it was twenty-eight.

Looking over the list of members dropped it is somewhat discouraging to note that of those dropped for dues a large percentage of the members paid dues for only the year they became affiliated with the Society.

If the Society is to continue as a self-supporting organization, it must do one of two things: either interest more of the men and women engaged in fish culture, fisheries research, and fisheries management, or increase the membership dues of the active members. If we add more members we can then increase our print order for Transactions, thus decreasing the cost per copy of the proceedings. Surely there are plenty of co-workers among you who should join hands to make the Society a larger and more influential organization.

It is hoped that we may be able to make a better showing during the coming year, and especially that a number of our Mexican friends who are interested in the work of the Society may see fit to join with us in our effort to advance the fisheries program throughout North America.

Since the 1936 Transactions (66th Annual Meeting) were not yet off the press at the close of the fiscal year, no bills have been presented for printing and indexing that volume, hence we had no outstanding indebtedness as of the end of the fiscal year.

During the past year we were able to return to the Permanent Fund $250.00 of the $500.00 borrowed to meet heavy expenditures during the previous fiscal year.

The Executive Committee of the Society held a meeting last night to discuss various phases of the Society's activities, and to dispose of such items of business as were found necessary to the success of this Annual Meeting. None of the matters so disposed of is of sufficient importance to deserve special recording in the published Transactions of this meeting.

The financial status of the Society is as follows:

TREASURER'S REPORT

July 1, 1936 to June 30, 1937

General Fund

Receipts

Balance on hand July 1, 1936		$ 59.56
Annual Dues:		
Individuals and Libraries		
For the year 1932-1933	$ 3.00	
1933-1934	3.00	
1934-1935	9.00	
1935-1936	68.00	
1936-1937	945.96	
1937-1938	335.00	1,363.96
Clubs and Dealers		
For the year 1936-1937	50.00	
1937-1938	45.00	95.00
State Membership		
For the year 1936-1937	180.00	180.00
Sale of Transactions		290.47
Sale of Index		25.00
Sale of Separates, 1935 Transactions		331.64
Exchange on Checks		1.10
Balance on hand Petty Cash Fund		.46
Total Receipts		$2,347.19

Disbursements

Transactions		
1935, vol. 65		
Balance on printing	$ 150.00	
Separates	360.36	$ 510.36
1936, vol. 66		
Reporting	121.50	
Proofreading	35.00	156.50
Rental Safe Deposit Box		5.50
Postage		176.14
Office supplies		8.52
Balance of Petty Cash Fund deposited		.46
Stationery and printing		50.87
Clerical and Secretarial expense		
Seth Gordon	100.00	
Ethel M. Quee	150.00	
Extra assistance	7.50	257.50
Express		8.72
Miscellaneous		2.30

Refund		
Membership dues	6.00	
Transactions	28.00	34.00
Exchange on checks		3.12
Telegraph		3.13
Insurance		13.76
Premium on bond		18.75
Returned check		6.00
Repay loan to Permanent Fund		250.00
Total Disbursements		$1,505.63
Receipts General Fund	$2,347.19	
Disbursements General Fund	1,505.63	
Balance on hand July 1, 1937		$ 841.56

PERMANENT FUND

RECEIPTS		
Balance on hand July 1, 1936		$ 378.40
Interest on savings account	$ 14.31	
Interest on mortgage certificates	253.74	
Dividends on Commonwealth Southern pfd.	30.00	
Loan to General Fund repaid	250.00	548.05
Total Receipts		$ 926.45
DISBURSEMENTS		
None		
Balance on hand June 30, 1937		$ 926.45
Par value of certificates		5,000.00
Par value 10 shares Commonwealth Southern, pfd. @ $100 each		1,000.00
Total		*$6,000.00

*The market value of certificates during the past year has been far below par, but since there is no open market no established cash value is available. The cash value of the 10 shares of Commonwealth Southern Preferred, par value $100 as of June 30, 1937 was $466.25.

The Secretary-Treasurer also begs to report that from July 1 to August 4, 1937, inclusive, additional receipts in the General Fund amounted to $624.76, and expenditures totalled only $36.79, leaving a balance in that fund as of August 4 of $1,429.53, with no outstanding obligations because the bill for the 1936 Transactions has not yet been presented.

The report of the Secretary-Treasurer was received and referred to the Auditing Committee, and later upon recommendation of the Committee was approved as submitted.

REPORTS OF STANDING COMMITTEES

REPORT OF THE COMMITTEE ON FOREIGN RELATIONS

W. F. Thompson

Since the last report of this Committee events of outstanding international importance have occurred both on this continent and elsewhere. In the last report it was strongly recommended that the already cordial and successful cooperation of the nations sharing the fisheries of this continent be developed and supported by the creation of definite procedure to establish joint policies. It was urged that this be done before other nations enter and complicate the at present relatively simple and direct situation. It was specifically urged that thorough consideration of treaties to deal with the haddock fishery of the Atlantic and the fisheries of the Great Lakes be initiated at an early date, and that the pending Fraser River Sockeye and Pacific Halibut treaties be promptly acted upon. During the last year the two latter treaties have become effective by the exchange of ratifications. The other recommendations remain, and should be supported in every way possible by the Society.

There is no need in this report to review the international situation on this continent so fully treated last year. The multiplicity of contacts between Canada and the United States was then dealt with at some length. The present meeting, in Mexico City, should however serve to emphasize the desirability of furthering in every way closer relationships between nations in the southern part of this continent. In the past a great deal of attention has naturally been paid to these relationships in the north, but it is becoming very apparent that every consideration which has been urged as regards Canadian-American relations applies with equal force to all other sections.

Of primary importance from this point of view is the increasing clarity with which great dangers can be seen in the present methods of reckless international competition. Inherent in these methods are exhaustion of home banks and a resultant speedy expansion to those of other nations. In this connection, the greatest significance should be attached to the Convention between the countries around the North Sea signed in March, 1937, regulating the size of mesh used, the sizes of fish landed, and providing a continuing representative body to formulate further action. It as yet does not have the cooperation of France, and has not been ratified by the several countries concerned. But it puts into the form of an international agreement certain features of legislation already adopted by the countries concerned, among which may be cited as an example the very far-reaching Sea Fisheries Protective Act of Great Britain. Despite the general feeling that the Convention is far from what it should be, it is of the greatest significance as indicating first, virtually, general acknowledgment of the fact of overfishing and consequent underproduction; and second, an earnest attempt to meet the situation in the only way it can be met, internationally.

For many years the dangers of overfishing have not been fully faced, either in Europe or elsewhere throughout the world, and a great contributing factor in this failure has been the long continued argument over the real condition of the North Sea, one of the longest exploited and most heavily fished areas in the world. It is therefore most noteworthy that general admission, both by scientists and by fishermen, has been made that overfishing has most seriously affected these fisheries, and others, and that only international action can rebuild

them. In this Convention there is recognized the very considerable progress which has been made in the formulation of definite and desirable principles of treating and of rebuilding fisheries, a recognition taking the form of a provision that the International Council for the Investigation of the Sea, a group of scientists, shall constitute the advisory body to the representatives of the several nations.

Of significance also is the recent move by Iceland to secure cooperative closure of a part of Faxe Bay, outside its territorial waters, a part in which young and small fish form a particularly large fraction of the catch. This move was made at the recent session of the International Council at Copenhagen in July, 1937, and the response which can be secured cannot as yet be known.

In American waters the need for immediate attention to the procedure of international cooperation has been brought prominently to the fore by the constantly increasing feeling over the coming of Japanese ships to banks off the American coast. This is, it should be realized, an incident in the world-wide expansion of nations which find their own banks insufficient. It emphasizes the need for definite policies and methods of meeting the very difficult situation which will arise with increasing frequency.

The Foreign Affairs Committee calls the attention of the Society to the most satisfactory progress which has been made by the final exchange of ratifications for the revised Pacific Halibut Convention and the new Convention for the rebuilding of the sockeye fisheries of the Fraser River. It recommends that this Society express its earnest hope that the work of the Commission appointed thereunder will be most successful. Your Committee wishes, however, to point out that, great as this progress has been, there remains the greater task of formulating and making effective the joint policies which the United States, Canada and other nations of this continent already hold in common. The halibut and salmon conventions represent but two of the many possibilities, and their continued success, as well as that of others which may from time to time be thought desirable, will depend, in the opinion of this Committee, upon the strength and permanence of the more general principles of these joint policies.

Upon motion, duly seconded, the report was adopted.

REPORTS OF SPECIAL COMMITTEES

REPORT OF THE POLLUTION STUDY COMMITTEE

TALBOTT DENMEAD, *Secretary*

Your Secretary is far from satisfied with the progress made in cleaning up polluted waters during the past year. However, this is not the fault of your Committee, for it has not been standing still. All its members have been intensely interested in cleaning up or controlling pollution, and have done all they possibly could; nearly every member is connected with at least one other organization interested in the subject, which has received some of the credit for their activities.

There seems to be some misunderstanding on the part of several members as to what are the duties and functions of the Committee; they seem to be of the opinion that your Committee is expected to make scientific investigations. This was not the purpose for the appointment of this Committee, as I understand it. We were appointed to investigate the situation and methods of stopping pollution, not what is pollution, or what waters are polluted. If I am wrong why was a lawyer selected for the first Chairman, and a lawyer for Secretary?

It seems to me the Society should consider the present situation, decide what

it wants its Pollution Committee to do, and give some instructions. Your secretary has been in touch with various members of the Committee during the past year; we have tried to hold meetings, whenever a few members happened to be in a city attending some meeting or conference, but never have there been more than three or four members able to get together. There has been considerable correspondence, and newspaper clippings relative to specific cases of pollution have been accumulated. The members have tried to suppress pollution wherever there was an opportunity, but there probably is as much pollution today as there was a year ago. In my report a year ago, I stated: "The problem now appears to be a legal one—how to suppress future contamination of waters by laws which can be enforced." I am still of the same opinion.

I do not know of anything the Committee could have done that it did not do. You, doubtless, recall the Committee was authorized to act in regard to federal legislation controlling pollution. The Lonergan Bill, pending in the Senate, appeared to suit the majority. Then the Barkley Bill was introduced in the Senate, providing a million dollars a year for investigations, etc., and there resulted a deadlock. Recently, I am informed, the Barkley Bill has been amended by inserting four or five paragraphs from the Lonergan Bill, principally the enforcement provision, which shall not become effective for two years; the clause relating to state compacts, which was not originally in the Barkley Bill; and an agreement that the U. S. Public Health Service shall administer the law.

The bill was reported out of committee in the Senate about August 12th, and passed that body a few days later. It then went to a conference between members of the Senate and the House—the Vinson Bill having already passed the House, which was similar to the Barkley Bill—but the conferees failed to get together after three conferences, and Congress adjourned without taking any further action on the agreed upon measure. Senator Lonergan writes: "We hope for a successful conclusion of the conferences next session (January, 1938)." An excellent review of the situation will be found in the Congressional *Record* of Saturday, August 21, 1937.

The Black Bass and Anglers Division of the U. S. Bureau of Fisheries obtains an annual report from its 125 deputies scattered throughout the States east of the Rockies, and it is interesting to note in their July, 1937, reports that a large number say the pollution situation in their section has improved, through establishment of municipal sewage systems and in other ways.

Upon motion, duly seconded, the report of Mr. Denmead was adopted.

Mr. I. T. Quinn of Alabama offered a motion, which was duly seconded, that the Pollution Study Committee be continued for another year. The motion prevailed.

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF THE DIVISION OF FISH CULTURE

A. D. Aldrich

In submitting this report an effort has been made to compile and summarize those statistics and information that seem pertinent to the fisheries in general. A complete report of activities would not be possible in brief form, because of the variation of methods, policies, environment, and circumstances encountered over so large an area. Each region has peculiarities which must be dealt with individually. This report will touch upon those factors which, it is hoped, might be of interest to all.

First we wish to take this means of thanking all those who so generously replied to the questionnaire sent each State Department. Thirty-eight states replied, and that information is the basis of this report. These facts are not new to most of you from the States, but may be helpful in some small measure to our neighbors in Mexico, who we hope may profit by many of our past experiences.

It is almost impossible to report accurately on the extent of fish culture in the United States because of the overlapping of interests and activities between the various states, the U. S. Bureau of Fisheries, and many organizations, sportsmen's leagues, etc. Figures in this report are therefore approximations.

Suffice to mention here that the various states operate some three hundred hatcheries, and the U. S. Bureau of Fisheries over eighty. These four hundred institutions have an annual production of well over ten billion fish of about forty-five species, costing over three million dollars. This figure includes, of course, administration and protection. Over six hundred men are employed to operate these hatcheries; their average wage is approximately $110.00 per month. Fortunately for them, this consideration includes living quarters in most instances.

Twenty-six of the states reporting have a board of non-salaried commissioners administering the affairs of fish and game propagation. Ten have salaried directors or a single commissioner.

Nine fish and game departments operate under civil service, and twenty-seven states offer no security to employees in that respect. Sixteen states have trained biologists for scientific fisheries research, and eleven hold regular courses of instruction for training their employes.

It is difficult to determine the extent of development or expansion of propagation facilities made through the various Public Works agencies. From the reports received it is apparent that such facilities have been increased perhaps 10 per cent.

The most interesting and important part of the reports concerns the opinions of various officials regarding the results of all this great propagation system. Supply the angler with a better creel is the principal purpose. An increase in this annual harvest is the justification for all the expense involved.

Inquiry as to what factors might be considered most vital in accomplishing this end resulted in the following opinions:

Eleven states advocate more hatcheries. Twenty-one consider the planting of larger fish the answer. Nine states request more laws, and more law enforcement. Twenty-two are basing their hopes on lake and stream improvement.

These factors should be of special interest to officials of Mexico in the preservation of their fisheries resources: the improvement of lakes and streams, and the planting of larger fish. In other words, we are admitting that before any amount of artificial propagation will improve the yield, the waters stocked must be a suitable place for fish. The lakes and streams must be capable of supplying all the necessities for maintenance, growth, reproduction, and protection of the fish population. Waters must be stocked in proportion to their capacity to supply these necessities. The same careful, scientific consideration must be given the transportation, planting, protection, welfare, and harvesting of fish as is devoted to their propagation. Fish production just begins when the fish leave the hatcheries. Unless they reach the creel of some happy angler, our efforts have been in vain.

The reports, and comments, received indicate that we are realizing the necessity for a more balanced program, that efforts to restore good angling must be based on a complete management system which includes all the factors mentioned, as well as a vigorous educational campaign to enable the fishing public to understand and assist in such management that it may be inaugurated before commerce and industry, and exploitation, have destroyed the habitat of fishes. Then the burden of artificial propagation will be much lighter, and the results more fruitful.

Such a program will be the result of further cooperation between the various states and Federal agencies concerned, and continuation, and perhaps expansion, of research activities, especially stream and lake surveys such as are being conducted by the Bureau of Fisheries, the National Park Service, the Forest Service, and several state departments. Data accumulated by each of these divisions of government must be assembled and made available for practical application, and distribution to every branch of the fisheries interests. A universal fish policy, which this Society has been working toward, should improve the efficiency of all the fisheries units.

It is logical that such authentic data be preserved and assembled in permanent form in the transactions of this Society. Comment, and exchange of ideas and practices, should be encouraged through the pages of that splendid publication, the Progressive Fish Culturist. That publication has, and may well continue to, acted as the clearing-house for exchange of ideas and final conclusions for the many problems that confront the fish culturist. Much costly duplication of effort and experimentation may be avoided by a more universal application of its contents.

A motion was made and adopted that the report of Mr. Aldrich be approved.

REPORT OF THE DIVISION OF COMMERCIAL FISHING

M. C. JAMES

A report upon the commercial fisheries might as well be made to an association of economists as to the American Fisheries Society, since probably the most vital problem affecting the welfare of the industry is that of marketing. Evidence of this lies in the fact that the National Association of Marketing Officials has created a special committee from its membership to study and report on matters pertaining to the marketing, standardizing, and grading of fishery products. The Federal Government, through operation of a cooperating marketing unit in the Bureau of Fisheries, has attempted to contribute towards solving the problem. Further than this an appropriation has been made to enable the Bureau of Fisheries to establish a market news service for the fishery industry. This function will be operating within the next several months.

The "raw material" aspect of the commercial fisheries has presented its problems during the past year. The perennial problem of depletion of some of the most desirable species in the Great Lakes is receiving its share of attention. A slight but perceptible progress has been made toward the principal objective of formulating and enforcing regulations applying to all of the Lake States and Canada.

On the East Coast, the conservation officers of the shad producing states have become seriously alarmed at the depletion of this important species. At a conference in New Jersey in February, a loosely coordinated continuing organization was set up with the idea of fostering all practical measures for shad conservation. An outcome of this is a shad marketing survey already conducted by the Bureau of Fisheries, and a proposed extensive biological survey, which will get actively underway within the next six months.

The New England States have been impelled to take further steps to stem the depletion of lobsters. In addition to overhauling their regulations to some extent, cooperating arrangements have been entered into with the Bureau of Fisheries in Massachusetts and Maine, for the resumption of lobster propagation at Federal hatcheries located there.

The International Fisheries Commission (Halibut Commission) of the United States and Canada has continued its efficient and effective program of control, and it is virtually conceded that the North Pacific supply of halibut is amply

safeguarded. Marketing difficulties have here, too, been a most vexing problem.

A further international fishery problem, which has attracted outstanding attention, is the presence of Japanese fishing vessels off the Coast of Alaska. Public attention has been directed to this development because of the claim that a new fishery there would be a threat to the Alaska salmon runs, which became stabilized through adequate Federal control and regulation for more than a decade.

That part of the industry dependent on the Columbia River salmon run has expressed alarm at the possibility of disastrous effects upon the fish through the erection of the tremendous dams at Bonneville and the Grand Coulee. The states concerned and the Federal Government, together with the agencies responsible for the construction of the dams, have collaborated in a program which, it is believed, will safeguard the run. Aside from the fish ladders and elevators contemplated, there is a program for artificial propagation set up which may be put into effect if the fish-passing devices fail to meet expectations. No possibilities, either biological or engineering, have been overlooked in devising a means to assure perpetuation of the Columbia River salmon.

In conclusion, I would state that this is probably the first time that a report on the status and well being of a two hundred million dollar interest has been condensed into two pages. I claim credit, however, for not having the temerity to attempt to suggest any solution of the various problems which have been touched on so briefly. The industry itself, the state authorities and the Federal Government are well aware of these problems and are working jointly and individually toward a solution of them. I believe that the principal contribution which the American Fisheries Society can make in this connection is to extend its support and backing on a broad basis without attempting to participate in the multiple individual aspects.

A motion was made, duly seconded, and carried that the report be adopted.

REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

WM. J. TUCKER

During the last year, with Legislatures in session in virtually all of the States and at the National Capital, you will well understand that there were many laws proposed and a considerable number passed affecting angling and to regulate the taking of the fishery resources of the country. Principally through the assistance of Mr. Talbott Denmead of the U. S. Bureau of Fisheries, I am enabled to present to you herewith a report summarizing some of this important legislation and regulations promulgated or proposed during the year.

I make no claim whatsoever that the report is complete. If there are those here representing States where important legislation was enacted or regulations promulgated, and if these matters are not covered in this report, I trust you will do me the favor of reporting to the secretary of this convention so that he may incorporate these items in the report which is herewith submitted.

Since all constructive fisheries work is dependent upon revenues provided for that purpose, and usually such revenues come from the sale of fishing licenses, you will be first interested to know how license laws were amended.

Licenses—Alabama has adopted a resident rod and reel angler's license costing $1.00 for all over 16 years of age.

Georgia requires residents of the State fishing with artificial bait in either fresh or tidal waters to have a license costing $1.25.

South Carolina also passed a resident license law requiring the resident of the State to obtain a fishing license costing $1.10 (artificial bait, rod and reel); the non-resident license fee was lowered to $5.25, and a short term license for two days, costing $1.10, was also adopted.

The Wisconsin legislature adopted a sportsman's license, covering hunting, trapping and fishing, with minimum cost of $5.00. Out of each fee, $3.00 goes to the regular license fund, and the remainder to provide more public hunting and fishing grounds.

Vermont raised its non-resident license fee from $3.15 to $5.15, provided a 14-day license costing $2.35, and a 3-day license costing $1.65.

Minnesota raised the non-resident license fee from $3.00 to $4.00, but I am informed a bill has just passed the House providing for the reduction of the fee to the old rate of $3.00. Minnesota also provided a 5-day license for Big Stone Lake costing $1.00.

Arkansas raised its 15-day tourist license fee from $1.10 to $1.50.

Mississippi now has a 3-day license costing $1.25.

Maine increased its resident license fee from $0.65 to $1.15.

Connecticut now permits a man over sixty-five, resident of the State, to obtain a hunting and fishing license for $0.35.

Ohio provided a resident angler's license costing $0.50, and also one on Pymatuning Reservoir, costing $1.50, with a ten cent fee in addition.

Wyoming's non-resident license fee is now $5.00, having been raised from $3.00.

The joint council of the Shoshone and Arapahoe tribes in Wyoming have decreed that fishing on the Wind River Reservoir by any person other than Indians shall be only through a permit system, and that the white man's money shall be paid for a permit.

Texas provided a $0.55 license for anyone above the age of seventeen years who fishes in twenty-one named counties of the State.

Seasons—The average angler and fisheries administrator is always profoundly concerned with any change that is made in the regulations providing open seasons. Here are some of the changes that were made last year:

Arkansas provided an open season on grab or grabbling with hands on rough fish from June 1 to September 1.

Florida adopted a 60-day closed season on black bass from March 15 to May 20.

Colorado shortened the open season on trout and grayling.

The Supreme Court of the State of Iowa held that the Iowa Commission did not have the authority to regulate seasons in the State, and owing to this decision the season on trout and other game fish remained closed until the legislature could enact the necessary legislation.

West Virginia opened its trout season (brook, brown and rainbow) on May 1, to continue until July 5 this year, and by regulation also changed the season on black bass, opening it July 1 instead of June 28, and provided an open season on muskellunge, walleyed pike, pike or pickerel from July 1 to April 15.

Connecticut provided a closed season on perch from February 10 to April 14.

New York established an open season for bullheads in Lake George from July 15 to May 31.

Missouri changed the trout season from May 30 to March 31, to March 1 to October 31.

Oregon opened its trout season ten days later than usual.

Indiana extended the trout season two months.

Limits—Bag limits are often taken as a legal restraint on the angler, or as a mark for him to try to achieve. Considerable changes were made in the limit laws during the year.

Florida has placed a limit on the number of tarpon which the angler may retain—all but two must be returned to the water; a transportation limit of two in possession was also established, and their commercialization prohibited.

Indiana reduced the size limit on crappie to 5 inches; lowered the size limit on pike perch from 15 to 10 inches; established a limit of six for pike or pickerel with no size limit; reduced the limit on trout to fifteen, and established a 7-inch limit on Loch Leven trout, with bag limit of fifteen.

New Mexico established a 6-inch limit on crappie (exception); ring perch

and yellow perch, 40; bream and other sunfish, 20; catfish 25 pounds and one fish with minimum size limit 8 inches; and pike perch ten per day with minimum size limit of 13 inches.

Pennsylvania established a daily limit of twenty-five on all fish. It also legalized Sunday fishing.

New York established a daily limit of ten on northern pike or pickerel and pike-perch; and a limit of fifteen on pike-perch in Oneida Lake, or twenty-five when two or more persons are angling from the same boat; eight black bass in the State of New York with the exception of Lake Ontario and the St. Lawrence River, where the limit is ten. Where four or more persons are angling from the same boat, they may take not to exceed thirty in one day. A minimum size limit of 6 inches on smelt was repealed, and trout cannot lawfully be taken or possessed anywhere in the State less than 7 inches.

Tennessee increased the size limit on black bass from 8 to 9 inches, and trout from 6 to 7 inches, with daily limit of ten, and established a daily limit of ten on crappie, and ten on walleyes with 10-inch limit.

Arizona decreased the daily limit on trout from twenty fish or 15 pounds to fifteen fish or 10 pounds.

Oregon by regulation established a 6-inch limit on trout in all waters east of the Cascade.

Changes in Fish and Game Form of Government—The American Fisheries Society is always interested in changes that are made and the form of government affecting fisheries in the various states. Here are some of the changes that were made last year.

California increased the number of members of the Game and Fish Commission from three to five.

Missouri adopted the Commission form of administration for its fish and game work by constitutional amendment.

Georgia now administers its fish and game work by a Division of Wildlife of the Department of Natural Resources instead of by a Game and Fish Commissioner.

Colorado adopted the Commission form of administration.

Wyoming made changes, among them being the period of appointment of commissioners.

Texas created a Coastal Division, segregating the work of that division from other activities of the Texas Game, Fish and Oyster Commission. The Coastal Division, however, remains under the direct supervision of the Commission.

Other Legislative Activities—This has been a particularly active year in game and fish work. In New Hampshire fifteen bills, later merged into two bills, were introduced in the legislature.

In Massachusetts, Conservation Commissioner Ernest J. Dean made seven specific recommendations for new legislation, among them being one to clarify the law which permits the Commissioner to regulate hunting and fishing in State forests and parks; another to reduce from twenty-five cents to fifteen cents the fee of town or city clerks for issuing fishing licenses; another provided for the issuance of hunting and fishing licenses to certain aliens; and another to provide complimentary hunting and fishing licenses.

A bill was introduced in Utah to raise the combination fishing and hunting license fee from \$3.00 to \$4.00, the additional \$1.00 to go into a special fund for fish and game enforcement; another bill to permit the State Fish and Game Department to acquire lands and water rights to be used for the conservation and propagation of fish was also introduced; another to permit males over seventy and females over sixty to fish for non-game fish without a license.

A determined fight was underway in New Jersey to repeal the striped bass anti-netting bill, passed last year, and California found itself in the throes of a battle to repeal its striped bass law, which was defeated.

The Fish and Game Committee of the General Assembly of Connecticut received a total of thirty bills, among them being one to provide a license for the

taking of minnows; granting persons over seventy the right to fish without a license; reducing license fee for farmer-landowners of more than 5 acres of unposted land to $1.00, plus a recording fee, instead of the usual $3.35 rate; a reduction to $2.50 for combination hunting and fishing license; and to authorize hunting and fishing licenses costing $1.35 for residents of the state owning not less than 25 acres. To increase the minimum length on striped bass from 12 to 15 inches and establish a creel limit of ten striped bass per day; reduce creel limit on trout to five pounds, or not more than ten trout per day. Changes in the season on yellow perch, pickerel, pike, and trout were also recommended.

Repeal of the "red worm" law was enacted in Oklahoma.

Michigan considered establishing a trout license.

In California a bill was introduced providing for a limit of five tuna and yellowtail, ten barracuda, and three white sea bass.

A bill was introduced in Indiana to raise the resident license fee from $1.00 to $1.50.

A bill was introduced in the Nevada legislature to clarify the present laws and to provide for the payment of fines into a fish and game fund instead of the county fund to counteract a proposed reduction in the appropriation for the Fish and Game Commission.

The Maine legislature has before it a bill to lower the age limit for junior fishing licenses, and another to provide for junior guides.

Montana had bills pending to increase the cost of fish and game licenses, and to provide separate fishing and hunting licenses for residents costing $2.00, and combination licenses costing $3.00; to raise the cost of non-resident licenses from $3.00 to $5.00, and raise the non-resident license fee for a 15-day license from $1.50 to $2.00.

A bill was introduced in New Jersey prohibiting fishing in trout streams before April 5.

New Mexico gave bull-frogs protection.

The Governor of California signed an anti-pollution bill which adds two months to the season when anglers may fish streams without disturbance by hydraulic mining.

A bill was introduced and given favorable committee report to permit the Texas Commission to make necessary regulations governing fishing. This bill did not achieve final passage. Effort of the Texas legislature to prohibit drilling for oil in tide-water areas was unavailing.

Miscellaneous—An old law in the District of Columbia protecting fish in that area was used to kill a proposed bill providing for construction of an abattoir in the District.

Conservation is now one of the compulsory subjects that must be taught to school children in Wisconsin.

In California fishing is allowed in one of its lakes provided the angler pays "two-bits" a pound for the bass he keeps.

A motion was made and adopted that Mr. Tucker's report be approved.

REPORT OF THE DIVISION OF ANGLING

KENNETH A. REID

Angling is the criterion of fisheries programs. We need more intelligent fish management rather than increased production and stocking.

Generally speaking, and with a few notable exceptions, public fisheries programs have consisted mainly of mass production schedules with little or no exact knowledge of the results obtained from resultant stocking, and even less of the waters in which the fish are planted.

The science of fish culture has made commendable progress, but the science of stream and lake management has lagged sadly behind. In the mad race to

produce the greatest number or tonnage of fish for the annual or biennial report, rational care and management too often ends when the fish are checked in on the delivery truck.

Artificial propagation is a necessity under present day conditions of intensive fishing. However, it is only a means to an end, and that end is improved fishing. The mere production and planting of large numbers of fish may contribute nothing toward that end unless they are intelligently distributed in waters suited to them, and unless these waters are properly managed afterward. Failure to recognize the importance of these factors has resulted in a tremendous waste of fish and a general decline in fishing in spite of increased production.

Artificial propagation and raising of fish is a specialized science. It presents enough problems to occupy the full time of the culturist and tax his knowledge and ability without saddling him with responsibility for management programs outside of the production field. If he does his job well, he will have no time to devote to problems of management in a fisheries program beyond the production of fish, and because of his specialization is apt to be peculiarly ill fitted for directing the other essential activities.

This is not to be construed as a criticism of fish culturists, but rather of the system under which they operate, which frequently fails to make the essential distinction between the raising of fish and their intelligent management after they leave the hatcheries or rearing ponds. These two sciences, while commonly considered as one, are as wide apart as the sales and credit departments of any big business, and they should be so separated.

It is rare indeed to find a fish culturist who is also an ardent angler. He is essential to angling, but usually knows little about outside conditions governing this sport or the means for improving it aside from the production of more fish. It is unfair to expect the average specialized fish culturist intelligently to direct the distribution of fish after they leave the hatcheries or to manage the fishing waters. It is only natural where they do that emphasis is placed on production of fish and the rest of the fisheries program is a hit or miss proposition.

We should have more exact knowledge of fishing waters, their suitability for certain species, and their carrying capacity—and this knowledge should be the basis for production schedules. Too often the reverse has been the case. The hatcheries have raised the species that suited their convenience, or which made the best showing for the funds expended with little regard for their suitability to the waters or their effect on fishing. The result of such a reverse program looks much better on the paper report than it does to the angler out fishing public waters.

The tremendous production of wall-eyed pike fry, common to most northern states, is a case in point. It bulks large on the official reports, but its benefit to angling is frequently questionable, to say the least. Instances are numerous where repeated plantings have failed to produce any mature fish, but even more tragic are the many cases where such plantings have succeeded to the ruination of existing bass fishing, and promiscuous distribution has done more harm than good to the cause of angling. It is a reasonable assumption that the relative ease and low cost of propagating wall-eyes as compared with bass has been a determining factor in the mass production of the former rather than angling considerations.

The brook trout is another instance of blind production and distribution. For years he has been the favorite of the fish culturist and many states continue to give him a major place in production schedules even though the benefits to angling have long been known to be negligible in most waters. Not only does the brook trout seem unable to adapt himself to the changed conditions obtaining in most of our larger trout streams, but even where he does seem to thrive he is seldom able to stand the gaff of intensive fishing long enough to attain a decent size.

There has been more sentimental foolishness, both in the ranks of anglers and fish culturists, over the brook trout than any other species. Entirely aside from the general lack of results from stocking, eastern anglers are fast waking up to the fact that the brook trout is really inferior to both the rainbow and the brown as a real game fish. The sooner anglers and fisheries agencies put sentiment and prejudice aside and realize that the brown trout, and secondarily the rainbow, are the trout of civilization, and map their programs accordingly, the sooner we will be on a sane and sound fisheries program as far as trout are concerned. In the Rocky Mountain region the cutthroat occupies much the same position as the brook trout of the East. His abundance is now confined largely to the more remote sections while the rainbow and brown have replaced him in most accessible major waters.

The case of the brook trout in the East and the cutthroat in the West is similar to that of the prairie chicken, which has been replaced over a large part of its range by the ringneck pheasant and Hungarian partridge because of fundamental changes in environmental conditions. Since we cannot immediately remedy these environmental changes, if ever, we will do well to recognize this fact and work with those species which will thrive under existing conditions, rather than waste time and money in a vain attempt to bring back the natives.

Some eastern states have gone extensively into the production of trout above legal size on the premise that fingerling trout would not survive. Where this is really true, the streams are not real trout streams, and the question is pertinent whether it might not be better to re-classify some of them and stock them with warm water species that could thrive.

In considering the question of fingerling versus large trout for stocking purposes, it is essential that we differentiate between the species. It is probably true that the stocking of brook trout fingerlings is largely a waste of time and money, for practically all of the suitable spring runs tributary to our eastern trout streams are plentifully supplied with brook trout fingerlings from natural reproduction. But unfortunately these little fellows do not seem to migrate to the main stream, but form a stunted indigenous race in the tributary, living their life cycle there and often spawning at a size below the legal limit. Obviously where this is the case it would avail nothing to stock additional fingerlings of this species.

But the behavior of brown and rainbow trout fingerlings is entirely different. When stocked in small tributary runs, they remain there only until they gain a few inches in length, when they migrate down and automatically stock the main stream. By late fall or the following spring most of them will be in larger waters while the little brook trout remain in the spring runs.

The production of trout above the legal limit by a public fisheries agency as the sole means of maintaining trout fishing is an economic fallacy. Every fish culturist knows that the average fishing license will not pay for raising and distributing a single daily creel limit, yet many of them have put out a lot of publicity designed to create the impression that they were stocking plenty of large trout to fill the baskets of the anglers. In doing so, they are merely inviting justifiable criticism as the anglers' high hopes sink to despair on the streams. Furthermore, many anglers who have been fortunate enough to catch some of the survivors of the fish-hog-truck-following-fisherman, are becoming increasingly disgusted with the comparison of these fish with wild ones or those grown from fingerling size in the stream.

Granting that it is essential to stock legal trout in some streams or none at all, and that it is desirable in some heavily fished waters to stock a few really large ones to add spice to the fishing, the general practice is not only economically unsound, but encourages bait fishing as opposed to fly fishing, and plays into the hand of the meat fisherman as opposed to the sportsman angler. Hatchery trout of large size may "go wild over night" on occasion, but they commonly lose in weight and condition, if they are fortunate in surviving a month or more.

The experience of the past decade has demonstrated that intensive stocking alone is inadequate to replace the fish taken from heavily fished waters. During the last eight years, by reason of changed economic conditions which provide the average citizen with vastly more leisure, the number of *man days* of fishing has increased tremendously, although the number of individual licenses and the total income from this source has shown no appreciable increase. The net result, as far as maintaining fishing is concerned, amounts to the same thing as selling a dollar and a half license for about a quarter, as compared with 1929.

Considerable improvement can be effected by intelligent management of fishing waters so as to give Nature the maximum opportunity for cooperating in our fish rehabilitation programs. Too often this powerful ally has been ignored in our man-conceived plans. But when everything that is humanly possible has been done, and Nature has been accorded the position of a respected partner in the enterprise, fishing w[illegible] still be unsatisfactory in accessible waters according to present standards of the average angler.

It is obvious to any student of angling conditions, considering the present and growing intensity of fishing, that it is utterly impossible to bring about any general improvement without materially altering the viewpoint of the average angler toward the sport. As angling has increased, waters suitable for maintaining fish life have decreased through the inconsiderate and short-sighted onslaughts of our so-called civilization, which looks on a running stream as a depository for all undesirable wastes, an avenue for an obsolete means of transportation requiring governmental subsidies to exist, a source of electric power, or a means for creating through irrigation "more farm lands to make more overproduction to make more farm relief necessary." And whether the agency directing such activities be a public or private one, the effects on fish life and angling are always blandly ignored. The net result is that today there is simply not enough suitable fishing water properly to accommodate the vast and growing army of anglers according to their present standards of angling success.

Most daily creel limits are entirely too liberal. They may have been all right twenty years ago, but they come nearer representing the limit of fish that each angler of today should take annually if he would enjoy really improved fishing. There is no alternative: either the anglers will drastically reduce their kill, or they will continue to "enjoy" the unsatisfactory quality of fishing about which they are now complaining.

Creel limits have a psychological effect on the average angler which is only intensified by the senseless playing up of limit catches by newspapers, magazines and even some state conservation publications. Such ill-advised publicity merely encourages the competitive spirit and induces many anglers to look on the daily creel limit as par on the fishing course. As these limits are commonly far above the normal yield of the waters, they tend to encourage persistent fishing rather than curtail it, and failing to attain "par" the average fisherman is doubly dissatisfied. If these limits were reduced to a number that could normally be taken by the average angler, he would be better satisfied because he would feel that he had succeeded in his fishing; and fishing would be improved through the resultant curtailment of kills on the unusual days when present limits are taken.

Public fisheries agencies will do well to face these facts squarely, admit their inability to supply the fish demanded for the creels instead of putting out misleading publicity in a defensive attempt to justify their existence, and frankly tell the anglers that the future quality of their fishing depends more upon their attitude toward what constitutes angling success than upon any other factor. If they continue to measure success by the number of dead fish brought in, they may be sure that they will continue to "enjoy" the present unsatisfactory quality of fishing, for they can take fish out of the waters faster than Mother Nature and fisheries agencies combined can put them in.

It has been conclusively demonstrated by several large scale experiments that excellent fishing can be maintained, even in intensively fished waters, where the

fish hog is kept under control and the kill is reduced to a fraction of that permitted by state law. Furthermore, such experiments have proven that the mortality of fish caught and returned to the water can be kept as low as one-half of one per cent. There need be no curtailment in the sport of angling, but merely a sensible curtailment in the kill of fish—the source of that sport.

Considering the fact that the average angler pays about ten dollars a pound for the game fish he catches, whether he realizes it or not, it seems rather silly and uneconomical for him to catch and kill for food, or to satisfy his own vanity, a game fish which he prizes so highly as sport, when in doing so he is depleting the source of that sport, and when he can buy equally good fish food in the market for a few cents a pound. It is a question of sport versus meat, sportsmanship versus selfish vanity; and in the final analysis the answer to the fishing problem lies squarely at the feet of the army of anglers.

But fisheries agencies can help materially in this accomplishment. They are the logical ones to launch and lead this essential educational movement. If they will divert the money and energy now being spent in self glorification and publicity that does nothing to improve fishing, to this educational work and frankly tell the anglers these simple facts, the investment will pay large dividends in improved fishing, which will automatically be the best publicity they could possibly get. The Pennsylvania Fish Commission summarizes the whole problem concisely in its slogan: IF YOU WOULD CATCH MORE FISH—*KILL LESS!*

THE PRESIDENT: Is there any discussion on the report by Mr. Reid?

There was no discussion, and a motion was made and prevailed that the report be adopted.

APPOINTMENT OF COMMITTEES

Auditing—A. D. Aldrich, *Chairman*, Joe Hogan, Carl D. Shoemaker.

Resolutions—Talbott Denmead, *Chairman*, L. R. Donaldson, T. H. Langlois, I. T. Quinn, Juan Zinser.

Nominations—Fred Westerman, *Chairman*, Elliot Barker, Frank T. Bell, J. D. Chalk, William J. Tucker.

Time and Place—Arthur L. Clark, *Chairman*, Herbert Davis, P. J. Hoffmaster, David H. Madsen, H. W. Shawhan.

Publications Committee—Secretary Gordon presented recommendations of the Executive Committee with reference to the Publications Committee, which, after amendment, were adopted as follows:

WHEREAS, It is highly desirable to achieve continuity in the work of the Publications Committee, therefore

BE IT RESOLVED, That only one of the five members of this Committee be replaced each year, each new member to serve for five years, unless special circumstances make other or additional action necessary;

BE IT FURTHER RESOLVED, That each succeeding President shall at the beginning of his term of office appoint the new members and designate the Chairman of the Committee. All of the members of this Committee for the next ensuing year, 1937-38, shall be appointed by the incoming President, who shall designate the length of appointment for each member varying from one to five years.

After the adjournment of the annual meeting President-Elect Quinn, in ac-

cordance with the foregoing action, appointed the following Publications Committee:

Dr. Lauren R. Donaldson, Seattle, Wash.	5 years
Dr. Paul R. Needham, Palo Alto, Calif.	4 years
Dr. John Van Oosten, *Chairman*, Ann Arbor, Mich.	3 years
Prof. W. J. K. Harkness, Toronto, Canada	2 years
Dr. John R. Greeley, Albany, N. Y.	1 year

REPORTS OF COMMITTEES

AUDITING COMMITTEE

MR. A. D. ALDRICH: Your Auditing Committee has checked the books of the Secretary-Treasurer for the fiscal year ending June 30, 1937, and finds the report correct as submitted.

Your committee recommends that the total appropriation for clerical and stenographic services for the year 1937-1938, exclusive of expenses in connection with the preparation, proof-reading and indexing of the Transactions, be the same amount as last year, namely $350.00.

(Upon motion, duly seconded, the report of the Auditing Committee was adopted.)

COMMITTEE ON RESOLUTIONS

MR. TALBOTT DENMEAD: Your Committee on Resolutions submits the following resolutions for the consideration of the Society:

1. Federal Aid for Fisheries Work

WHEREAS, Neither the U. S. Bureau of Fisheries nor the various States have available sufficient funds to keep the sport fishing resources of the country up to the standard demanded by the ever-increasing numbers of anglers who, with more leisure time and modern transportation facilities, are able to fish oftener than formerly; and

WHEREAS, Approximately $400,000.00 in excise taxes on fishing tackle are collected annually from fishermen;

THEREFORE, BE IT RESOLVED, That this organization favors legislation which would provide Federal aid through the U. S. Bureau of Fisheries to the States for development and maintenance of fishing resources by devoting the tax on fishing tackle to cooperative fisheries projects, such legislation to give the States legal recognition in the selection of projects and in fixing the standards to which such projects shall conform.

(Upon motion, duly seconded, the resolution was adopted.)

2. The Late Chas. F. Thompson

WHEREAS, Conservation and our membership has lost a friend in Charles F. Thompson of Illinois, who passed away, Sunday, August 22nd, 1937;

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society in 67th Annual Conference in Mexico City, this 24th day of August, 1937, deeply feels the loss by death of the Hon. Chas. F. Thompson, Director of Conservation of the State of Illinois, and hereby expresses its sincere sympathy; and

BE IT FURTHER RESOLVED, That a copy of this resolution be forwarded by our Secretary to the family of our deceased co-worker.

(Upon motion, duly seconded, the resolution was adopted by a rising vote.)

3. Appreciation of Courtesies

WHEREAS, The meeting of the American Fisheries Society is closing its sixty-seventh annual conference; and

WHEREAS, The Society is indebted to the Mexican Government, the high officials of the country and Mexico City, and others for the many courtesies;

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society assembled in Mexico City, this the 24th day of August, 1937, does hereby express its appreciation for the courtesies and hospitality extended it, its members and guests during their too short visit in historic Mexico, a great and fascinating country; and we appreciate all that has been done for us in making our conference so pleasant and successful, and tender our sincere thanks in the form of this resolution.

(Upon a motion, duly seconded, the resolution was adopted by a rising vote.)

COMMITTEE ON TIME AND PLACE

MR. ARTHUR L. CLARK: Your Committee on Time and Place for the Fisheries Society, and Mr. Wm. J. Tucker, Chairman of the Committee on Time and Place for the International Association, submit the following joint recommendation:

> We, your Committee on Time and Place for the American Fisheries Society and the International Association of Game, Fish and Conservation Commissioners, beg leave to report that we met in joint session and by unanimous vote recommend that the next meeting of the Society and Association be held the third week in August at Asheville, North Carolina.

Mr. Wm. J. Tucker, after some discussion by the Society in reference to the proposed date of the next meeting, offered a motion, which was duly seconded, that the next meeting be held in Asheville, North Carolina, during the third week in June. The motion prevailed.

COMMITTEE ON NOMINATIONS

MR. FRED WESTERMAN: Your Committee on Nominations submits for your consideration the names of the following members to serve as your officers for the ensuing year:

Officers

President—I. T. Quinn, Montgomery, Ala.
1st Vice-President—Fred J. Foster, Seattle, Wash.
2nd Vice-President—T. H. Langlois, Put-in-Bay, Ohio.
Secretary-Treasurer—Seth Gordon, Harrisburg, Pa.
Librarian—Kenneth E. Cobb, Windsor Locks, Conn.

Vice-Presidents of Divisions

Fish Culture—Joe Hogan, Lonoke, Ark.
Aquatic Biology and Physics—Eugene Surber, Leetown, W. Va.
Commercial Fishing—Lester Smith, Port Washington, Wis.
Protection and Legislation—B. M. Brennan, Seattle, Wash.
Angling—James Brown, Frankfort, Ky.

Committee on Foreign Relations

James A. Rodd, *Chairman*, Ottawa, Canada.
J. D. Chalk, Raleigh, N. C.
Sr. Juan Zinser, Mexico City, Mexico.

W. F. Thompson, Seattle, Wash.
John Van Oosten, Ann Arbor, Mich.
Wm. J. Tucker, Austin, Texas.
Arthur Clark, Hartford, Conn.

We recommend that the Committee on Common and Scientific Names of Fishes be continued without change (See page 4).

(Upon a motion, duly seconded and unanimously adopted, the nominees as submitted were declared elected, and at the direction of the President the President-Elect was escorted to the chair amid applause, and properly presented.)

MR. I. T. QUINN: I do not believe any man has ever been elected as President of this Society who appreciates it more, and I do not believe anyone who has been elected will have a stronger cabinet. I want to congratulate the Nominating Committee on its selection of those various officers who will serve during the coming year. I am going to rely upon the cabinet and the Executive Committee to support me during the incoming term, and I think everyone of them will be given some definite duty between now and the meeting next year.

There is a great work ahead for this organization. We have been touching for years upon some of the fundamentals, and that is as it should be. I believe that there are some of the fundamentals which have not yet been touched upon seriously and definitely by this organization.

For example, when I study the situation in my own country, and when the experts tell me that three billion tons of our soil are washed into our streams filling them up and ruining the hundreds and hundreds of the best fishing streams in my country, I believe there is something the American Fisheries Society can do in furthering restoration programs along that line, and help to set up a program that will eventually restore at least some of the thousands of streams to a fishable condition.

There are many other fundamental problems that confront those of us who are interested in angling for sport and in the great American commercial fishery along the Coasts and in the Great Lakes. I believe that is all I have to say at this time.

MR. HERBERT DAVIS: As a point of information as to the procedure by which papers come before the Society, I should like to ask whether it is a matter of by-laws or a matter of custom. I refer to the fact that the submission of papers should be the same as on the program.

MR. GORDON: No member may present more than two papers. The Program Committee can reject a paper, or the Committee on Publications may refuse to have it printed.

MR. DAVIS: I asked the question because I desire to leave a suggestion with the Society at this time. This organization is growing, due to the fact that most of the states of the United States each year more and more recognize the value of the scientific research which we are gradually bringing into this field, until we are going to have a membership and such a number of papers that it will be impossible to handle them.

I would like to suggest to the President and the Executive Committee for this coming year that they give consideration to a procedure which has been followed in many of our large scientific organizations for a long time, one of which I can speak with first hand knowledge. The American Chemical Society has a policy committee on program and papers, which committee is made a part of the organization. The annual meetings are not spent in listening to a lot of papers.

The value of a paper does not come from the few minutes which the author may take in reading it or telling of it. It comes from its publication and study. I think such a committee should be set up in this Society and a very definite rule and policy laid down that those submitting papers should first pass

certain qualifications before their papers are considered for printing in the proceedings.

The second duty of the committee should be to select those papers which are officially to be placed on the program. In that way you are going to make it possible to limit your program to a workable meeting, and the papers presented will only be those of the utmost importance, and particularly in reference to new developments. Progress reports, rehashing of advancements in research that has gone on in the past, are valuable for printing in the journal but have no particular value for presentation at a meeting, and I recommend to you, Mr. Chairman, that you and the Executive Committee give some thought to reviewing the proceedings of other scientific organizations with the view of following out that plan. Otherwise we are going to be faced with a program too large, too cumbersome, and too uninteresting.

THE PRESIDENT: I thank Mr. Davis for his suggestions. I think they are fruitful and we shall be glad to give such consideration as the committee deems best for the Society in working out a program.

Is there any other discussion, transaction or business to come before the meeting?

Mr. Westerman offered a motion, which was duly seconded, that the meeting give a rising vote of recognition for the able services of the retiring President, Dr. Huntsman. It was so ordered.

DR. HUNTSMAN: I thank you gentlemen. It has been a great pleasure to be working with you. As expressed before, I have been at some disadvantage for two reasons, and I am very glad to know that those reasons will not apply in the case of our present President. Those two reasons are that first of all, although a very old member of the Society, I have not in the past been in position to attend as I wished. The other point has been that the meeting was in Mexico City and I, as President, was in the other extremity of this big North American Continent. It was desirable that I be in close contact with the chairmen of the other committees, but I was so far from Senor Zinser that I have been prevented from close contact.

The suggestion which has been brought up here as to the desirability of curtailing the program was considered by the Executive Committee and we had instructions as to handling the program; and so far as I know we carried through the program in time, as far as conditions permitted, and I believe, due to the work of Senor Zinser and his staff, we have had a very excellent program indeed.

(The Meeting Adjourned.)

In Memoriam

Dr. Nicolas Borodin, Los Angeles, California

H. F. Johnston, Bozeman, Montana

Honoré Mercier, Quebec, Canada

Frederic P. Moore, Locust Valley, New York

Rear Admiral Jefferson F. Moser, Alameda, California

Dr. E. E. Prince, Ottawa, Canada

Thomas W. Slocum, New York, New York

Smeaton White, Montreal, Canada

PART II

PAPERS AND DISCUSSIONS

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THE REGULATION OF THE FISHERIES IN MEXICO

SANTIAGO RODRÍQUEZ MÉNDEZ

Chief, Inland Fisheries Service, Department of Forestry, Game and Fish, Mexico

It is a known fact that fishing in sea waters and interior continental waters had attained great progress and development in the vast territory that today comprises Mexico at the time that the Spanish "conquistadores" came to America in the early part of the sixteenth century.

The Maya Indians in the Caribbean Sea, the Purépeches, descendants of the Incas of Perú, in the Lakes of Michoacán, and the Toltecs and Aztecs in the Lakes of the Valley of Mexico, considered fishing as one of their most important industries. Netzahualcoyotl in Textoco, and Moctezuma in Tenochtitlan, spent enormous fortunes in the development of the fisheries.

During the colonial period, the Government of Spain preoccupied itself to a great extent in the exploitation of fishing, and in the "laws of the Indies" we find important provisions decreed not only to protect natural resources but also the Indians or natives, to whom it reserved the prior right in the exploitation of the fisheries.

The Franciscan fathers, Sierra, Kino, and Salvatierra, missionaries who carried to our Península of Lower California and to what today constitutes the American State of California the civilization that prevailed three or four centuries ago, defended to the utmost the privilege of the natives to engage in pearl diving. Through the proceeds of these exploitations they contributed to the greatness of those missions that are the admiration of all who visit California.

The first governments of independent Mexico could not devote their attention to the fisheries and permitted, as did the laws of the governments of the Viceroyship, the exploiters of the Indian and of the wealth of the nation thus to become owners of the greater part of the Mexican fisheries and to make slaves of all workers devoted to fishing.

It was not until the middle of the nineteenth century that the governments of Juárez and Lerdo de Tejada again preoccupied themselves with our fisheries and our fishermen, issuing certain laws destined to protect our declining fishing industry.

After Juárez and Lerdo came the lengthy governmental period of General Porfirio Díaz, who in order to avoid further worries handed out all rights to fish in a few concessions. Again this most important industry, far from progressing, fell constantly in arrears, until the governments emanating from the Revolution found it in a deplorable state of almost complete abandonment.

It was President Madero first, and later Presidents Carranza, Obregón, Calles, and our present Chief Magistrate, General Lazaro Car-

denas, who since 1912 have endeavoured by all possible means to restore fishing to the dignity and importance that pertain to it. They wish to accord the benefits of these exploitations to the fishermen who risk and spend their lives at such work to develop the fisheries as a source of better food for the agricultural and urban populations.

President Madero in 1912 permitted free pearl diving. In 1915 President Carranza decreed free fishing in all waters of the Republic, and in 1916 founded the Department of Game and Fish. In 1923 and 1925, President Obregón issued the first regulations on game and fish. President Calles, in 1925, held the First International Fish Convention with the United States of America, for the purpose of considering the protection of our fishing resources of the Pacific Ocean, as a base of supply of a large part of the Mexican and American industries on those shores. President Rodríguez, in 1933, began the socialization of our fishing resources in view of insuring the patrimony and welfare of our riparian fishermen. President Cardenas during the last three years has accomplished the nationalization of fish exploitation in Lower California and has founded the first National Hatchery Stations for the improvement and the restocking of waters on a larger basis. This restocking program is designed to benefit all the waters of the Republic that were totally bereft of fishes, not only to provide fish for domestic consumption but for angling as well.

At this time scientific studies and investigations are being initiated in order to acquire a greater knowledge of our fishing resources, and to devise appropriate means of protection. Socialization of fishing is conducted on a larger scale, reserving for Mexican fishermen organized in coöperative associations the species of greater commercial importance. The formation of a large number of associations of this kind has taken place. These associations will be provided with the necessary elements for the development of their activities, all of which will be carried out with due regard for private initiative, and offering the necessary guarantees for the investment of capital to those who comply with our laws. All of this is being done in accordance with the postulates of our Six Year Plan.

The Autonomous Department of Forestry, Game and Fish hopes to obtain the sincere and most enthusiastic coöperation of all the members of this International Convention, in order that the worthy Head of this Department, Señor Ingeniero Don Miguel A. de Quevedo, may carry out the ideals of our Chief Magistrate, that express the soul and the feeling of the whole Mexican people.

Discussion

Congressman Kleberg (Texas): Mr. Chairman and members of the convention. I do not propose to take your time on this occasion, at the inception of your business session, but I would like to comment briefly on the subject which you have under consideration here—the conservation of fish, the wild-

life, and natural resources of the North American continent. The history of North America had its inception in the wildlife and natural resources of the entire continent.

Scientific developments of those resources will be brought out at this convention and the research made possible by the cooperative efforts of the various countries and those in attendance here should take definite cognizance of the past history of our natural resources and look forward to more fine and constructive work that is hoped to be attained by this meeting.

It is a distinct privilege and a great pleasure for me to be here with you as a representative in the Congress of the United States from the great State of Texas. It is always a pleasure for me to visit our neighboring country, Mexico.

I have always learned when I came to Mexico; and I find here the added opportunity to learn something with reference to one of the fundamental problems which confronts this meeting, that is, for each of the nations represented to procure the proper understanding and conception of the natural and basic resources, not only as an economic asset but, my friends, as a foundation for constructive education for the future.

I thank you for this opportunity. As a representative in the Congress I did not come here with any other objective than to take advantage of the opportunity of learning something so that I may better serve.

The President: We thank you, Mr. Kleberg, and I am sure we all appreciate what you have had to say to us.

SPONGE FARMING: A NECESSITY

Lewis Radcliffe

Executive Secretary, The Sponge Institute, Washington, D. C.

Abstract

This paper reviews the development of methods of cultivation and suggests a novel application of the methods used in oyster farming to sponge culture. It also contains reference to recent developments of sponge farming in the Bahamas and entrance of cultivated sponges of excellent quality into our markets. The world sponge trade is valued at $3,500,000 annually, the United States being the greatest market, amounting to 50 per cent of world production in 1927. It is shown that if the industry is to be maintained and sponges sold at reasonable prices, we must look to the cultivation of sponges to maintain an adequate supply.

Introduction

That the world fishery for sponges has not kept pace with the growth in population is evidenced by world production values of sponges—1907, $3,500,000; 4-year average 1925 to 1928, $3,799,171; 1935, $3,354,439. The United States is the largest consumer of sponges in the world. In 1907 the value of sponges consumed in this country was $945,823 (27 per cent of world production); 1927, $1,858,483 (50 per cent of world production); 1935, $1,213,155 (36 per cent of world production). With an adequate program of advertising, education, and trade promotion, it is conceded that the demand for sponges could be tremendously increased. Without such a program, the market has been able to absorb the catch at relatively high prices and this in turn has encouraged inventive genius to develop substitutes. Man has not yet been able to produce a substitute comparable in quality and price with the natural sponge. It is also generally conceded that any large increase in demand would put a strain on grounds already depleted which would lead to economic exhaustion. To the student of the fishery it is clear that certain obvious steps should be taken:

1. Surveys should be made to develop new potential sponge producing areas;
2. Laws governing the taking of undersized sponges and prohibiting especially destructive methods of fishing should be rigidly enforced and strengthened where necessary; and
3. As the preceding give little promise of building up the fishery to materially larger proportions over a long period of time, permanent growth of the sponge industry must depend upon the development of large scale sponge culture (farming) operations.

Sponge Culture

Experiments in Europe. As early as 1785, Filippo Cavolini recounted experiments carried out in the Bay of Naples showing that sponge cuttings would attach to foreign bodies and grow. In 1862 Oscar Schmidt repeated these observations and pointed out the application of these findings to commercial operations. The following year the Austrian government and certain merchants of Trieste established a station on the island of Lesina, one G. Buccich being given charge in 1867. Among the fruits of Buccich's investigations were the discovery that sponges can be removed from the water and cut in the air without injury; that it is best to handle them during the winter months and in cool damp weather; and that the cut surfaces will grow together or to certain foreign objects with which they are placed in contact. The failure of Buccich's experiments to yield commercial results apparently ended experiments in Europe.

Experiments in Florida. About 1879 a Mr. Fogarty of Key West, Florida, planted 216 cuttings of sponge attached to sticks and wires at a depth of about 2½ feet of water. Four specimens, reported to be 6 months old and sent to the National Museum in Washington, were said to have grown from four to six times the size of the original cuttings. Several years later R. M. Munroe of Cocoanut Grove, Florida, began experiments in Biscayne Bay, fastening cuttings to stones and stakes. A large proportion of the cuttings survived and showed some growth, practically all eventually being destroyed or lost. About 1897-98 Dr. J. V. Harris of Key West planted several thousand cuttings at Sugar Loaf Key, attaching the cuttings to galvanized iron wire laid on the bottom. As a result of corrosion and breaking of the wire, the sponges became detached and the mortality was very high. Dr. Harris also planted many thousand cuttings which were sowed broadcast over the bottom. The results were for the most part uncertain.

In January, 1901, under instructions of the Commissioner of Fisheries, Dr. H. F. Moore began a serious study of sponge culture at Sugar Loaf Key and at various places in Biscayne Bay. This study was undertaken not only for its scientific possibilities but also for the purpose of demonstrating the economic application of scientific findings. Moore (1910 b) found cement disks and triangles satisfactory for attaching the cuttings for use on rocky bottoms. On muddy or grassy bottoms spindles were attached to the triangles to elevate the sponge cuttings off the bottom and prevent their being smothered.

Rate of Growth. According to Moore, while the rate of growth of cuttings varied with conditions, in Sugar Loaf Sound the average annual increase in diameter was found to be about 0.75 inch, while at Anclote Key and Cape Florida it was from 1.0 to 1.2 inches. Later developments in Biscayne Bay indicated that the average growth of sponges planted on the bottom in Cape Florida Canal was slightly in

excess of the rate given above, while at Soldier Key, about 7 miles away, it was much less.

Shape and Quality. According to Moore (1910 b, p. 578), "Sponges grown on wires or spindles assume a spheroidal shape with a uniform texture of surface and devoid of any semblance of a 'root,' such as is found in all natural sponges excepting rollers. This form is very attractive and durable.

"Cuttings grown on disks tend to assume a flatter shape and the surface attached to the cement is plane, in that respect resembling the root of natural sponges, but instead of being 'raw' and exposing the canals it is covered with a close felt of great strength and durability, and forms the strongest instead of the weakest part of the sponge."

As the purpose of this paper is to attract attention to the economic application of sponge cultural methods rather than to summarize the findings of the scientists, the reader interested in the biological phases should study the findings of Moore and others.

Sponge Farm Areas

Moore suggests that the area for sponge growing be close to shore where the sponge farmer can live and guard his property, that is, in the regions of the keys. The area selected should not be subject to the effects of freshets and heavy rainfall, and areas in the vicinity of the mouths of rivers should, therefore, be avoided. Neither can any locality be regarded as safe where the specific gravity of the water frequently falls below 1.019 or 1.020 at 60° F. One should also avoid places where much sand is carried in suspension in the water.

Moore (1910 b, p. 584) gives the following computations as to the requirements for planting one acre with a sponge on each square yard of bottom:

"For plain disks:	
4,840 disks, at 2 cents	$96.80
4,840 cuttings, at 2 cents	96.80
Labor, planting, fifteen days, at $2	30.00
	223.60
"For disks with short lead spindles:	
4,840 disks, at 2½ cents	121.00
4,840 cuttings, at 2 cents	96.80
Labor, six days, at $2	12.00
	229.80

"The first cost is slightly in favor of the plain disks, the expense for aluminum binding wire being so small as to be negligible, but when it is remembered that both kinds of disks are available for subsequent plantings when recovered, this advantage disappears. Assuming that during four years of growth 20 per cent of the original cuttings die and the disks to which they were attached are lost on account of their inconspicuousness, each of the above accounts would have to be credited with the

value of the disks recovered, 80 per cent, amounting to $77.44 in the first case and $96.80 in the second, making the actual cost of planting in the two cases $146.16 and $133, respectively."

The author recognized that his calculations, although based on the actual results of experiment, were "largely theoretical and that definite data cannot be attained until the work is actually undertaken on a commercial scale" (p. 585). The practicability of sponge cultivation on a laboratory scale was amply demonstrated by this work.

Possible Adaptation of Oyster Farming Methods to Sponge Culture

Moore (1910 a, p. 406), discussing the reproduction in sponges, stated:

"In some species, at least, the sexes are separate, the females greatly preponderating, and the young are produced mainly if not solely from eggs. The young are, for a time, minute free swimming organisms which may be carried considerable distances by the currents, and they are still very minute when they at last settle down for permanent attachment. At this stage, like oyster fry, they are liable to be covered and suffocated by comparatively thin deposits of sediment and the object to which they can successfully attach must be hard and clean. It follows from this and from the fact that much of the sea bottom is more or less covered with soft deposits, however thin, that a vast majority of the young sponges fall on unsuitable bottom and are lost. This accounts in many cases for their irregular and sparse distribution on many rocky bottoms which superficial examination would indicate as favorable. The natural bars are undoubtedly capable of supporting a much heavier growth than they usually bear, and if partially grown sponges could be placed on them * * * * their productiveness could be enormously increased as these deposits of sediment, fatal to the spat, would prove innocuous to larger individuals."

Since the time of Moore's studies, tremendous advances have been made in the development of spat collectors for obtaining a better set of oysters. Since the methods of reproduction in oysters and sponges are similar, the young of both being free-swimming for a period and thus likely to be carried considerable distances by currents and both needing hard clean surfaces on which to set, it may be possible to adapt some of the oyster spat collector methods to sponge cultivation. The writer has suggested to the U. S. Commissioner of Fisheries that experiments be made in this field of research.

Sponge Farming in the Bahamas

A report from Joseph E. Newton, American Vice Consul, Nassau, Bahamas, dated June 21, 1937, stated:

"Sponge is cultivated in the Bahamas by private enterprises, the shallow water beds thus produced being located principally in the Northern Bight of Andros Island. It is reported that new beds will be opened near Abaco. The Government will allot protected areas to spongers who wish to plant artificial sponge, and is contemplating revising and expanding the regulations covering artificial culture.

"The production of artificial sponge locally is still insignificant, amount-

ing to less than one half of one per cent of the total sponge exports from the Colony. Opinion differs as to whether the artificially produced wool sponge surpasses the natural product. The artificial product is said to obtain a better price on the local market, but has not proven popular when shipped to Europe.

"The culture of sponge is practicable in the Bahamas, provided suitable localities are selected and necessary attention is paid to the selection of seed in the beginning. But the industry is in its infancy. Experiments are now being carried on to ascertain what shape discs should be adopted to enhance the commercial value of this product. The texture of this commodity depends entirely on the localities selected for planting; sponges planted in certain areas are subjected to their own peculiar characteristics. These sponges mature in three to four years from cuttings."

This report also states that the Bahamas Government has appointed four men from England to conduct scientific studies over a period of about five years. When they found that a sponge bed had been fished too much, the area was closed to fishing. The excellent sponges found after a closed period fully demonstrated the effectiveness of this method of protection.

During the past three years, some 220,000 cuttings have been planted and about 500,000 will be set this year. A shipment of 5,000 of these cultivated sponges received in this country comprised splendid specimens of the most desirable sizes, which resembled in appearance and strength the best Rock Island Wool sponges of Florida. This actual demonstration of the practicability of sponge cultivation has aroused hope among members of the sponge industry in this country of augmenting the supply from commercial operations and thus brightening the future outlook of the industry. Sponge culture, said Moore (1910 a, p. 508), "is constructive, aiming to add to the sponge supply of the future without particular regard to the source of supply of the present. It apparently offers the only hope of permanently maintaining the sponge fisheries in those countries in which they are now established. . . ."

"To secure to the people of Florida the conservation of the natural beds, for the maintenance of the fisheries already established, to regulate those which may be introduced in the future, and to provide for an increase in the sponge supply to meet the growing demands of civilization" (1910 a, p. 510), Moore made four recommendations, the first dealing with minimum sizes, the second and third prohibiting the use of certain types of equipment, and the fourth pertaining to sponge culture which reads as follows:

"State and federal laws should be enacted for the encouragement of sponge culture in both territorial and extraterritorial waters, securing to private individuals or corporations the sole use, under proper restrictions, of suitable areas of the bottom for the purpose of raising sponges by artificial means. In case of further depletion of the natural beds, or with the growth of demand and the failure to discover new and more productive grounds, sponge culture offers the only possible means of prevention of a practical sponge famine. With the development of sponge fields in other parts of the world which would be serious competitors with the depleted beds of Florida, the practice of an economic system of sponge culture is

the only means which would prevent the extermination of the lucrative sponge business of the state."

During 1936, sponges sold through the Tarpon Springs Sponge Exchange amounted to 418,839 pounds valued at $1,035,429, the first time in the history of the Exchange that sales exceeded one million dollars. This represented an increase of 8 per cent in quantity and 67 per cent in value as compared with sales of the preceding year. As previously pointed out, it should be possible to increase greatly the use of sponges in this country through advertising, education, and trade promotion. Scarcity of supply and further increases in prices may have the opposite effect. As the world's largest consumer of sponges our hope of permanence and stability appears to depend upon the development of sponge cultivation. This is a problem which should be of general interest to our neighbors to the south wherever there are waters suitable for growing commercial sponges.

In conclusion, the practicability of sponge cultivation having been definitely shown, may I point out to our Federal Bureau of Fisheries and to the government of Florida the very great importance of providing for the cultivation of sponges to augment the existing supply and to demonstrate its practicability so that private capital may ultimately carry on sponge farming and thus bring about a greater use of our waters in the growing of crops of benefit to the whole nation.

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REMARKS ON POPULATIONS OF THE SHAD (*ALOSA SAPIDISSIMA*) ALONG THE ATLANTIC COAST REGION[1]

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ABSTRACT

Several characters of shad from the Shubenacadie River, Nova Scotia, from Delaware Bay, and from Chesapeake Bay were studied in order to establish the racial nature of shad populations along the Atlantic Coast. For this purpose nearly 350 fish were secured. Counts of vertebrae, pectoral fin rays, and ventral scutes were established to be the best characters. Variation in the number of gill rakers from the different habitats is overshadowed by stronger influences of size or age, and for this reason the number of gill rakers is unsuitable for racial distinction.

The Shubenacadie shad showed the highest averages in all characters studied, by means of which they can be separated readily from fish of more southern localities. The Delaware sample was characterized by the smallest averages, while the Chesapeake shad occupied an intermediate position.

The length-classes and stages of maturity in samples analyzed corroborated the findings based on the morphological characters. Based upon the points established to date, it is possible to conclude that shad from the Shubenacadie River, Delaware Bay, and Chesapeake Bay belong to three distinct populations.

The catch of shad within Chesapeake Bay has decreased rapidly from 8,500,000 pounds in 1931 to about 3,500,000 in 1935, according to official statistics gathered by state and federal agencies (Table 1).

TABLE 1. PRODUCTION IN THE SHAD FISHERY OF CHESAPEAKE BAY

Year	Maryland (pounds)	Virginia (pounds)	Total (pounds)
1931	1,196,000	7,291,000	8,487,000
1932	1,667,000	4,848,000	6,515,000
1933	1,374,000	4,817,000	6,191,000
1934	885,300	4,104,400	4,989,700
1935	800,000	2,882,900	3,682,900
1936	570,000	1,614,700	2,184,900

During the 1936 shad season (February to end of May) even smaller catches were made. Local fishermen explained the failure of the fishing on the basis of the unusually cold winter of 1935-36, with heavy formation of ice even in the lower bay. However, a good run of shad in Virginia waters (Buckroe Beach and Back River) was reported around the end of February and early March, 1937. This run very soon dropped off, and a few weeks later very large catches of shad were reported along the New Jersey Coast and in the Hudson

[1]Contribution No. 17, Chesapeake Biological Laboratory.

River, New York. Commercial fishermen explained the curtailing of the catch during 1937 as the result of the stormy weather along the North Carolina and Virginia sea borders, which drove this body of fish out of the bay. In other words, according to the general belief among the Chesapeake fishermen, the same body of shad, instead of concentrating in the Chesapeake area, during the last two seasons (1936 and 1937), migrated to more northerly waters. The present preliminary investigation of shad populations along the Atlantic Coast was made in order to secure some of the information necessary to substantiate or to disprove this belief.

Sources of Material

Leim (1924), in his studies on the life history of the shad in Canadian waters, presented considerable material dealing with certain racial characters of this species from Nova Scotia. The data of Leim for the Shubenacadie River and Scotsman Bay are of particular importance. The Shubenacadie River empties into Minas Basin, the upper portion of the Bay of Fundy, whereas Scotsman Bay is situateted at the entrance to Minas Basin. Leim's data for the above localities were collected during 1920-23. They are incorporated in the present article and in Tables 3, 5, 6, and 7 are identified by asterisks.

The counts of the ventral scutes were made separately for the anterior and posterior series. Under the anterior series was understood the number of scutes located anterior to the ventral fins, the last scute of this series being that found at the base of the ventral fins (Berg, 1932, p. 71). As the first scute of the posterior series was counted the one situated immediately behind the ventral fins, the whole series being extended backwards to the anus. The total number of ventral scutes consists of the sum of the anterior and posterior scutes (Table 6). From comparison of our 1937 material from the Shubenacadie River with Leim's 1922-23 data from the same river, it is obvious that we have included in our anterior series one scute which Leim placed in the posterior series. In order to render the data comparable, we have in Table 6 increased Leim's counts of anterior scutes by one and decreased his posterior counts by one. Similarly, since Leim did not include the "hypural,"[2] we have increased his vertebral counts in Table 7 by one. For all of Leim's data, totals, averages, and the standard errors were calculated.

Of our two 1937 samples from Chesapeake Bay (Table 2), one was secured at the Conowingo Dam on June 4 and consisted of eighty-

[1]This fact was confirmed by a letter from Dr. Leim on November 16, 1937.

In papers dealing with the racial characters of fishes the term "hypural" is often employed. In reality it is better to replace it by the term "urostyle," which is defined by Hollister (1936, pp. 259-260) as "the posterior terminal vertebral segment or segments which follow the last undoubted centrum. The urostyle is considered as one in the total vertebral count." According to the same author, the "hypural" means "any bone that is ventral or posterior to the urostyle and supports one or more caudal fin rays or raylets." There are several hypurals in each urostyle. Clupeidae, for instance, possess seven hypurals, a number quite commonly found in other Isospondyli.

nine fish caught with a scoop net. Another was a sample of fifty buck shad taken with a pound net on June 3 at Spesutie Island, located near the mouth of the Susquehanna River. Both localities are at the head of Chesapeake Bay and are shown on the map (Area I) in the paper by Vladykov and Wallace (1938) in this volume. Tables 2, 7, 9, and 10 include all fish from both samples, but Tables 5, 6, and 8 include only fish taken in the Conowingo Dam on June 4. In Tables 4 and 5 each sample is treated separately.

Altogether almost 350 shad from Nova Scotia, Delaware, and Chesapeake Bay were examined (Table 2).

TABLE 2. SAMPLES OF SHAD ANALYZED

Locality	Date of capture	Number of fish	Length range in millimeters	Method of capture
Shubenacadie River, Nova Scotia	May 14, 1937	78	390-580	Gill net
Delaware City, Delaware Bay	May 10, 1937	99	420-530	Gill net
Conowingo, Maryland, Chesapeake Bay	June 2-3, 1936	28	410-510	Scoop net
Conowingo, Maryland, Chesapeake Bay	June 3-4, 1937	139	280-485	Scoop net & pound net

Morphological Characters

Characters selected were divided into several groups, according to the degree of variation due to susceptibility to environmental influences (Vladykov, 1934).

Unvariable Characters

The number of rays in the ventral and caudal fins are of this type. From Table 3 it is evident that shad samples, even from such widely separated localities as the Bay of Fundy (Scotsman Bay) and Chesapeake Bay have the same number of rays in the ventral fins, namely nine, the first a simple ray and the remaining branched. A slight variation in the number of rays in these fins has no practical significance for the purpose of distinction between different samples. The number of rays in the caudal fin, no doubt, is equally constant (Vladykov, 1934); consequently analyses of caudal rays were omitted.

The counts of rays in the ventral, as well as in all other fins, were done on excised fins, stained in alizarin and with the skin removed from one side.

Variation with Age

It is well known that in the Clupeidae allied species possess different numbers of gill rakers. Regan (1916, pp. 7-11), stated that *Alosa alosa* from the Atlantic coast of Europe has 58-85 gill rakers on the lower limb of the first branchial arch, while the African form

TABLE 3. FREQUENCY OF OCCURRENCE OF THE TOTAL NUMBER OF RAYS IN VENTRAL AND PECTORAL FINS

Locality	Number of rays 8	9	10	11	12	13	14	15	16	17	18	Total number of fish	Mean(M) number of rays	Standard error (σM)
Ventral fin														
*Scotsman Bay	5	241	1	0	0	0	0	0	0	0	0	247	8.99	±0.0009
Chesapeake Bay	1	41	1	0	0	0	0	0	0	0	0	43	9.00	±0.0003
Pectoral fin														
*Scotsman Bay	0	0	0	0	0	0	3	51	158	39	3	257	15.94	±0.0421
*Shubenacadie River	0	0	0	0	0	0	0	4	18	2	0	24	15.92	±0.1030
Shubenacadie River	0	0	0	0	0	0	1	11	50	16	0	78	16.04	±0.0716
Delaware Bay	0	0	0	0	0	2	2	33	55	7	0	99	15.62	±0.0730
Chesapeake Bay	0	0	0	0	0	0	10	30	82	14	0	136	15.73	±0.0635

*Data from Leim (1924).

TABLE 4. FREQUENCY OF OCCURRENCE OF GILL RAKERS ON THE FIRST BRANCHIAL ARCH FROM THE LEFT SIDE

Locality	Upper limb Range	Upper limb Average	Lower limb Range	Lower limb Average	Total number Range	Total number Average	Number of fish	Average length of fish in millimeters
Shubenacadie River	34-44	38.74	62-73	67.53	99-118	107.53	74	443.4
Delaware Bay	36-45	40.47	61-75	68.24	100-121	109.67	98	481.5
*Conowingo, Maryland	36-43	38.93	62-73	66.86	100-113	106.86	28	477.7
**Conowingo, Maryland	34-42	38.25	62-73	66.69	99-116	106.01	83	399.3
***Spesutie Island	33-41	37.09	57-69	64.70	91-111	102.78	46	346.1

*Date of capture: June 2-3, 1936.

**Date of capture: June 4, 1937.

***Date of capture: June 3, 1937.

(*A. africana*) has only 45. According to Evermann (1896, pp. 203-205), the Gulf of Mexico shad (*A. alabamae*)[3] can be separated from the more northern form (*A. sapidissima*) by the smaller number of gill rakers, which is less than fifty on the lower limb. Further examples are given by Vladykov (1934, pp. 117-118).

On the other hand, within any one Clupeid species, there is a variation in the number of gill rakers which is related to the age, or rather the size of the fish. Thus, Hildebrand and Schroeder (1928, p. 93) stated that in *A. sapidissima* from Chesapeake Bay they found "specimens 35 to 70 millimeters in length with 26 to 31 gill rakers on the lower limb of the first arch, specimens 110 to 180 millimeters long with 34 to 41, adults 413 to 580 millimeters with 62 to 76 gill rakers." The same holds true for the material from different localities examined during the present investigation. Table 4 clearly indicates the direct relationship between the number of gill rakers on the first branchial arch and the size (or age) of the fish studied. In other words, any possible relation of numbers of gill rakers to habitat is obscured by the much greater dependence of numbers of gill rakers on size of fish.[4]

From the above, it is obvious that the number of gill rakers in shad is unsuitable for distinguishing between populations from different localities.

Variation with the Habitat

This section deals with characters which appear to vary with differences in the environment where the fish live or, more specifically, with the conditions under which the shad spawn, eggs hatch, and fry develop. Although knowledge of these conditions is very incomplete, it is assumed that the racial differences are related to temperatures or latitudes (Vladykov, 1934).

a. Number of rays in the dorsal and anal fins. Table 5 summarizes the data on dorsal and anal fin rays. Under the term "well developed rays" is understood a number of rays clearly visible through the fin membrane, which consist of the last unbranched ray and all branched ones. In addition to these, there are from one to four anterior rudimentary rays in both dorsal and anal fins. The sum of well developed and rudimentary rays constitutes the "total number" of rays.

The number of well developed rays in both fins decreases from north (Shubenacadie River) to south (Chesapeake Bay), with the Delaware sample intermediate. This order also holds true for the total number of rays in the dorsal fin, but the total number of rays

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[3]Some years ago, Evermann (1902, pp. 277-283) described a third species of shad (*A. ohiensis*) from the Mississippi River Basin. With respect to numbers of gill rakers, this species occupies an intermediate position between the other two. It is to be regretted that as yet no one has made a thorough revision of the North American species of *Alosa*.

[4]Evermann (1902, pp. 203-205) presented a number of counts of gill rakers of *A. sapidissima* from different localities. Unfortunately, he did not indicate the size of fish examined, hence his data lost considerable in significance.

TABLE 5. FREQUENCY OF OCCURRENCE OF THE WELL DEVELOPED AND OF THE TOTAL NUMBER OF RAYS IN THE DORSAL AND ANAL FINS

Locality	Number of rays: 13	14	15	16	17	18	19	20	21	22	23	24	Total number of fish	Mean(M) Number of rays	Standard error (σ M)
Well developed rays—Dorsal fin															
Shubenacadie River	0	14	49	15	0	0	0	0	0	0	0	0	78	15.01	±0.0728
Delaware Bay	2	26	61	10	0	0	0	0	0	0	0	0	99	14.80	±0.0639
Chesapeake Bay	3	35	47	4	0	0	0	0	0	0	0	0	89	14.58	±0.0674
Well developed rays—Anal fin															
Shubenacadie River	0	0	0	0	1	4	33	23	16	1	0	0	78	16.67	±0.1078
Delaware Bay	0	0	0	1	0	17	47	21	9	4	0	0	99	19.30	±0.1101
Chesapeake Bay	0	0	0	1	2	12	40	26	5	0	0	0	86	19.20	±0.0991
Total number—Dorsal fin															
*Scotsman Bay	0	0	1	36	253	251	31	0	0	0	0	0	572	17.38	±0.0325
*Shubenacadie River	0	0	1	13	38	10	1	0	0	0	0	0	53	16.94	±0.1059
Shubenacadie River	0	0	0	1	13	51	13	0	0	0	0	0	78	17.97	±0.0741
Delaware Bay	0	0	0	2	29	58	10	0	0	0	0	0	99	17.77	±0.0657
Chesapeake Bay	0	0	0	5	38	42	4	0	0	0	0	0	89	17.51	±0.0716
Total number—Anal fin															
*Scotsman Bay	0	0	0	0	0	1	21	74	95	51	13	3	258	20.87	±0.0664
*Shubenacadie River	0	0	0	0	0	0	2	17	18	14	2	0	53	20.94	±0.1305
Shubenacadie River	0	0	0	0	0	0	1	8	31	27	9	1	77	21.49	±0.1190
Delaware Bay	0	0	0	0	0	1	3	14	50	18	9	4	99	21.06	±0.1134
Chesapeake Bay	0	0	0	0	0	1	3	16	36	25	5	0	86	21.12	±0.1057

*Data from Leim (1924).

in the anal fin of the Delaware Bay fish is smaller than that for fish from the other samples examined. Although the difference between total number of anal rays in the Delaware and Chesapeake samples is not satisfactorily[5] significant (Table 10), it is believed that the anal fin demonstrates the true differences between samples better than the dorsal fin. Reasons for such a belief will be given later.

The number of rays in both dorsal and anal fins given by Leim (1924) is considered throughout the present paper as a "total number," not as a number of "well developed rays" alone. The difficulty in counting these fin rays in fish of different sizes (many of Leim's specimens were young fish) is a probable explanation of differences found between the Nova Scotian samples examined by Leim and the sample analyzed during the present work. Therefore, the number of rays in dorsal and anal fins should not be considered as an easy and safe character for distinction between different samples.

b. Number of rays in the pectoral fins. In our opinion, the number of pectoral rays is a very important character, which can be used safely for racial studies. Table 3 illustrates this point clearly. Samples of fish from Nova Scotia examined by Leim in 1922-23 and the one obtained during the present study agree very closely, averaging sixteen rays. The Chesapeake sample ranks next with a mean of 15.73, while the Delaware fish showed the smallest number—15.62. The differences between the Shubenacadie and the Chesapeake samples are statistically significant, but the difference between the Chesapeake and Delaware fish is of doubtful significance (Table 10).

The sample of fifty buck shad taken on June 3, 1937, at Spesutie Island ($M=15.72 \pm 0.1037$) and that of eighty-nine shad, presumably from the same school, obtained next day at the Conowingo Dam at a distance of about 20 miles ($M=15.74 \pm 0.0860$), illustrate how closely average values for the number of pectoral rays can agree in the fish from the same school. Equally remarkable is the similarity in number of pectoral rays in different samples of Shubenacadie fish (Table 3). The difference between the Shubenacadie fish on the one hand and either Chesapeake or Delaware shad on the other is statistically significant, because the differences between means are respectively 5.0 and 6.6 times their probable errors (P. E.), but the difference between the Delaware and Chesapeake fish was only 1.8 times the P. E. (Table 10). The first ray in the pectoral fin is simple, while the remaining ones are branched.

c. Number of ventral scutes. Data pertaining to this character are

[5]Statistical analyses were made according to the formulae given by Chaddock (1925, pp. 240-241): $P.\,E.\,(M_1 - M_2) = \pm 0.6745 \sqrt{(\sigma M_1)^2 + (\sigma M_2)^2}$. In this formula P. E. stands for the probable error: M_1 and M_2 are respective means of two samples and σM_1 and σM_2 are standard errors of means in these samples. If the difference between means is three or more times the P. E. $(M_1 - M_2)$ then the difference is considered statistically significant. The P. E. $(M_1 - M_2)$ throughout the paper will be designated simply as P. E. If the difference between means is three times the P. E., then the chances against securing as great a difference between two samples of similar size from a homogeneous population are approximately 22 to 1. If the P. E. is equal to four, then the chances are 142 to 1, etc.

TABLE 6. FREQUENCY OF OCCURRENCE OF VENTRAL SCUTES IN FRONT OF THE VENTRAL FINS (ANTERIOR SERIES) AND BEHIND THE SAME FINS (POSTERIOR SERIES) AND OF THE TOTAL NUMBER

Locality	Number of scutes—anterior series					Total number of fish	Mean(M) number of scutes	Standard error (σ M)
	20	21	22	23	24			
*Scotsman Bay	4	57	126	64	0	251	22.00	±0.0475
*Shubenacadie River	0	13	35	3	1	52	21.93	±0.0863
Shubenacadie River	2	10	50	16	0	78	22.06	±0.0767
Chesapeake Bay	0	22	55	12	0	89	21.89	±0.0650

Locality	Number of scutes—posterior series								Total number of fish	Mean (M) number of scutes	Standard error (σ M)
	11	12	13	14	15	16	17	18			
*Scotsman Bay	1	0	4	36	199	257	68	4	569	15.63	±0.0354
*Shubenacadie River	0	0	0	5	27	24	7	1	64	15.56	±0.1155
Shubenacadie River	0	0	2	7	44	21	4	0	78	15.14	±0.0915
Chesapeake Bay	0	0	1	14	55	18	0	0	88	15.02	±0.0686

Locality	Total number of scutes						Total number of fish	Mean(M) number of scutes	Standard error (σ M)
	34	35	36	37	38	39			
Shubenacadie River	0	2	6	45	19	6	78	37.26	±0.0928
Chesapeake Bay	1	3	22	43	15	4	88	36.91	±0.0980

*Data from Leim (1924).

TABLE 7. FREQUENCY OF OCCURRENCE OF THE TOTAL NUMBER OF VERTEBRAE

Locality	Number of vertebrae									Total number of fish	Mean (M) number of vertebrae	Standard error (σ M)
	52	53	54	55	56	57	58	59	60			
*Scotsman Bay	1	0	1	1	12	52	89	13	1	170	57.41	±0.0774
*Schubenacadie River	0	0	0	0	11	30	21	2	0	65	57.22	±0.0940
Shubenacadie River	0	0	0	0	10	49	15	4	0	78	57.17	±0.0804
Delaware Bay	0	0	2	26	33	31	5	2	0	99	56.17	±0.1050
Chesapeake Bay, 1936	0	0	0	1	6	21	0	0	0	28	56.71	±0.1010
Chesapeake Bay, 1937	0	0	7	7	26	88	17	0	0	139	56.81	±0.0625

*Data from Leim (1924).

summarized in Table 6. Although the number of scutes in the Chesapeake sample in both series is smaller than that in Nova Scotia fish, these differences are not as great as was found for the number of pectoral rays or of vertebrae. The difference between total numbers of scutes in Shubenacadie and Chesapeake shad is more pronounced and is statistically significant (Table 10). The total number of scutes, as was demonstrated, can be used for racial purposes, but with reservations.

d. Number of vertebrae. Number of vertebrae is one of the best characters; hence it is widely used to distinguish between different local populations (Vladykov, 1934). The vertebrae were counted after splitting the fish along the back and removing the flesh from the left side. The hypural (or better, urostyle) was included in the counts. From Table 7 it is evident that, in the material from the different localities, the number of vertebrae varied from fifty-four to fifty-nine. The highest average number was found in the Shubenacadie shad ($M=57.17$), the lowest number in the Delaware fish ($M=56.17$). The Chesapeake shad taken in 1937 had a mean of 56.81; the mean of those obtained in 1936 was 56.71.

Leim's material from Scotsman Bay had a greater range, extending from fifty-two to sixty vertebrae, with a mean of 57.41, the greatest mean number of vertebrae as yet reported for the American shad.

It is of importance that repeated samples from Shubenacadie River, one of which was taken in 1922-23, and another fifteen years later, revealed practically the same number of vertebrae (Table 7). Similarly, the samples of shad from Spesutie Island ($M=56.82\pm0.0977$) and Conowingo ($M=56.81\pm0.0820$) taken on June 3 and 4, 1937, respectively showed complete identity.

The present study revealed that not only do the Shubenacadie shad differ significantly from both southern localities but the Chesapeake and Delaware samples also differ significantly (Table 10). On the other hand, Chesapeake Bay fish of 1936 and 1937 agree closely. The variation in the number of vertebrae is directly comparable with that of the pectoral rays or the total number of ventral scutes.

Physiological Characters

Under this heading we shall mention briefly the data presented in Tables 8 and 9 which deal with spawning and growth of the fish.

Spawning

From Table 8 it is evident that in the Shubenacadie fish the sex ratio is nearly 1:1, the males predominating only slightly (53.9 per cent). Among the Delaware fish the ratio of males to females was about 1:2, while the reverse holds true for the Chesapeake sample. These differences may indicate different spawning conditions of fish examined. The Shubenacadie fish were taken during active spawn-

ing, the Delaware at the beginning of spawning, and the Chesapeake near the end of the reproductive season. These statements are based on the relative numbers of fish in different stages of maturity.[6] Three stages, *pre-spawning, spawning,* and *spent* are mentioned in Table 8. The pre-spawning stage includes all fish in stages of maturity ranging from 1 to 3, using the 6-digit system; the spawning fish are in stages 4 and 5, while spent fish are designated as stage 6.

TABLE 8. SEX RATIO AND MATURITY STAGES, EXPRESSED AS PERCENTAGES

Locality	Pre-spawning		Spawning		Spent		Sex ratio		Number of fish
	Male	Female	Male	Female	Male	Female	Male	Female	
Shubenacadie River	33.3	11.1	59.5	88.9	7.2	0.0	53.9	46.1	78
Delaware Bay	3.5	44.3	96.5	55.7	0.0	0.0	29.3	70.7	99
Chesapeake Bay	0.0	30.8	7.9	30.8	92.1	38.4	85.4	14.6	89

Since the Shubenacadie and Delaware samples were taken on about the same date, the differences in the spawning conditions of the samples might be due to racial differences between these populations (Table 8).

Length-Classes

Length of fish throughout the paper is understood as the distance from the tip of the lower jaw to the fork of the tail.

Although the Shubenacadie fish had the greatest range in length (Table 9), it was, on the average, smaller than the Delaware fish or fish from Conowingo taken in 1936 (Table 4). The largest specimen was a female from the Shubenacadie River and measured 580 millimeters. The smallest fish measured 280 millimeters and was a male taken at Spesutie Island on June 3, 1937.

Unfortunately, in the literature there are only scanty data on age of shad, namely from northern localities, Nova Scotia (Leim, 1924) and Connecticut (Borodin, 1925, and Barney, 1925). If the correspondence between age and size described by these authors is correct, it can be judged that the material gathered during the present investigation consisted of several year classes, for the size range of the present samples includes several groups interpreted by them as year classes. The Shubenacadie material is characterized by groups of fish that range from 400 to 439 millimeters and from 440 to 479 millimeters, each of which classes was equal to about 42 per cent of

[6]The authors dealing with the classification of stages of maturity in fishes are Maier (1906), Pravdin (1926), Bull (1928), and Hickling (1930), who gave also extensive references. It is to be regretted that as yet there is not a single classification which is followed generally. In the present paper the same 6-digit system, which proved to be very useful for the haddock (*Melanogrammus aeglefinus*), was consistently employed. The details are given by Vladykov (MS.).

TABLE 9. LENGTH-CLASSES OF SHAD EXPRESSED IN MILLIMETERS

Length-class	Shubenacadie River, 1937			Delaware Bay, 1937			Chesapeake Bay, 1936			Chesapeake Bay, 1937		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
280-319	0	0	0	0	0	0	0	0	0	4	0	4
320-359	0	0	0	0	0	0	0	0	0	26	0	26
360-399	2	0	2	0	0	0	0	0	0	64	1	65
400-439	28	4	32	6	1	7	4	1	5	24	5	29
440-479	12	22	34	17	14	31	2	8	10	2	5	7
480-519	0	9	9	6	47	53	0	17	17	0	2	2
520-559	0	0	0	0	8	8	0	0	0	0	0	0
560-599	0	1	1	0	0	0	0	0	0	0	0	0
Total number of fish	42	36	78	29	70	99	6	26	32	120	13	133

the entire sample. The Delaware shad and fish from Chesapeake Bay in 1936 were dominated (about 53 per cent) by the class ranging from 480 to 519 millimeters. The Chesapeake fish of 1937 were much smaller than those of the other samples, the class 360-399 millimeters predominating (50 per cent). Two other classes, 320-359 and 400-439 millimeters, were about equally abundant (each amounted to 20 per cent of the sample). Other classes were represented by a very small number of fish.

The difference between length-classes in the samples from the localities studied suggests that shad from these localities belong to different local populations.

Discussion

Racial Differences

To summarize the above data, it can be stated definitely that samples of shad from the Shubenacadie River and Chesapeake Bay possess several characteristics which constitute strong evidence that these localities possess their own shad populations. This evidence is based first of all on differences in number of vertebrae and pectoral fin rays. The total number of ventral scutes may be considered also as a useful character (Table 10).

According to the general rule (Vladykov, 1934, pp. 102-105), fish from more northern localities possess a higher number of vertebrae and other numerical characters than specimens of the same species from more southern waters. On this basis, it was logical to expect that shad from Delaware Bay should have a higher number of vertebrae than Chesapeake fish. In reality, the sample of 1937 showed the opposite. Hence, it is not improbable that the Delaware sample consisted of shad whose origin was not local, but, on the contrary,

from a more southern section. Furthermore, the sample in question represented a population differing from both Shubenacadie and Chesapeake samples (Table 10).

TABLE 10. COMPARISON OF THE SIGNIFICANCE BETWEEN DIFFERENCES OF THE MEANS OF CHESAPEAKE BAY SHAD OF 1937 (139 FISH) WITH THOSE OF THE SHUBENACADIE RIVER AND DELAWARE BAY

Character	Shubenacadie River P.E. (M_1-M_2)	Delaware Bay P.E. (M_1-M_2)
Vertebrae	5.3 (H)*	5.4 (S)**
Ventral scutes:		
Anterior series	2.7 (H)	....
Posterior series	1.5 (H)	....
Total number	4.1 (H)	....
Pectoral rays	5.0 (H)	1.8 (S)
Dorsal rays		
Well developed	6.7 (H)	3.4 (H)
Total number	7.2 (H)	4.1 (H)
Anal rays:		
Well developed	6.3 (H)	1.3 (H)
Total number	3.5 (H)	0.6 (S)
Number of fish	78	99

*(H) Signifies a higher mean than that of the Chesapeake Bay sample.
**(S) Signifies a lower mean than that of the Chesapeake Bay sample.

On the assumption that each population has its own dominant year class, due to favorable conditions prevailing in certain years, the difference between length-classes may be equally important for racial distinction. Favorable years may be similar in different localities, but more probably they will be different.

Mixing of Different Populations in the Ocean

Although the data presented here indicate that each locality possesses its own shad population, the possibility of mixing of different populations in a given locality is not excluded. Recently it was observed (Vladykov, 1936) that during the unusually cold March of 1935 between twenty-five to thirty shad, each weighing from 4 to 6 pounds, were taken per haul in the Canadian otter trawls (on March 8) in about 50 fathoms, southwest of the Middle Ground Bank (about 44° 25′ N. Lat., 61° 05′ W. Long.). The presence of shad so far offshore suggests the possibility of the mixture of different shad populations there. Further evidences of such a possibility were secured by tagging experiments on shad in Chesapeake Bay during the spring of 1937 (Vladykov and Wallace, MS.). The results of this prelimi-

nary experiment are to be discussed in detail in a subsequent paper. Here it can be stated that one shad, 425 millimeters long, tagged at Spesutie Island, Maryland, on June 2, 1937, was recaptured thirty-nine days later by Mr. Peter Marino (Everett, Massachusetts) at Race Point, Cape Cod. Definite data on mixture of different shad populations along the seashore, especially in bays and rivers, are practically lacking.

Recommendation

It is highly desirable that more complete analyses of shad populations along the Atlantic Coast be made. In order to reveal the true nature of local populations, these analyses should be based, not only on characters treated in the present article, but on the study of scales. In this connection can be quoted the observations by Lea and Went (1936, p. 5), who stated that "it has been known for a long time that the annual rings in the scales belonging to herring of separate tribes, and living in different areas of the sea, present very varied pictures." They contributed important literature dealing with the herring (*Clupea harengus*). Nesbit (unpublished manuscript) found that scales of squeteague (*Cynoscion regalis*) are very useful in tracing migrations and in distinguishing races of this species. More extensive tagging of shad at the entrance of Chesapeake Bay, as well as in North Carolina, and the mouth of the Hudson River, is urgent.

It is the principal aim of this preliminary account to call the attention of conservationists in the states along the Atlantic seaboard to the need for scientific studies of the shad, a species formerly of great economic importance, which is now showing a marked decline in abundance. Work of a comprehensive nature can not be accomplished in a single state; full cooperation of the states concerned is essential.

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IS THE STRIPED BASS (*ROCCUS LINEATUS*) OF CHESAPEAKE BAY A MIGRATORY FISH?[1]

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Abstract

From October 8, 1936 to June 3, 1937 some 1,563 striped bass were tagged. The great majority of these fish belonged to the 1934 year class, which was extremely abundant in Chesapeake Bay.

During nine months 632 recaptures, or 42.4 per cent, were made. There is sufficient evidence that at least 300 tags from recaptured fish were not turned in as yet. Although these data indicate very intensive fishing, they are by no means conclusive as to the percentage of the striped bass population removed by the fishery within the bay, since the ratio of tagged fish to unmarked ones was unknown.

The great majority (97.5 per cent) of the recaptures was made within Chesapeake Bay, and only eighteen fish, or less than 2.5 per cent, were taken outside of the bay. During October, 1936 when the principal tagging at Galesville and Tilghman was done, the great majority of returns was taken locally. From the middle of November to the first week of December fish were recaptured on their down-bay migration as far south as the James River, Virginia. From the end of February to the end of April fish migrating up-bay were caught principally in Tangier Sound and the upper Potomac River. These localities are probably the chief spawning grounds for Maryland striped bass.

The results of tagging in the James River indicate that the local fish belong to a distinct school, which is evidently non-migratory. The recaptures of tagged fish outside of Chesapeake Bay were made from February through the entire summer of 1937, from Delaware to Massachusetts inclusive. Not a single tagged fish was recaptured south of Chesapeake Bay.

Introduction

Data on migration of the striped bass or rock (*Roccus lineatus*) within Chesapeake Bay are very scanty (Hildebrand and Schroeder, 1928; Truitt, Bean, and Fowler, 1929). Pearson (1933, pp. 15-17) tagged 305 rock during July and August of 1931 in order to determine the movements of these fish in the bay. All these fish, ranging in length from 10 to 15 inches, were taken on hook and line and were released, after tagging, at the place of capture, about 1 mile east of Hackett's Point, off Annapolis, Maryland. Over a period of twelve months eighty-six tagged fish were recaptured. Only nine fish out of the eighty-six were taken south of the Severn River (Figure 1). These preliminary data led Pearson to the conclusion that "the striped bass evidently preferred fresh or slightly brackish water and did not appear to seek the saltier water lying farther down the bay." In order to get more nearly complete information on the migratory nature of the rock, 1,563 of them were tagged during the period from October 8, 1936, to June 3, 1937. Of this number, forty-two fish were tagged and released by Capt. L. Seldon Taylor, Master of Police

[1]Contribution No. 18, Chesapeake Biological Laboratory.

Boat "Will F. Kellam," Norfolk, Virginia, in the James River, while the remaining were tagged by us in Maryland waters. Table 1 summarizes the data on tagging.

Method of Tagging

The type of tag used in the present investigation was suggested by Mr. Robert A. Nesbit of the U. S. Bureau of Fisheries and is similar to that used by previous investigators, namely Pearson (1933), Clark (1934 and 1936), and Merriman (1937). The tags consisted of two discs of celluloid, 0.025 inch thick, one-half inch in diameter, and provided with a center hole 0.32 inch in diameter. One of the discs was red and the other white. The tags were attached to the fish by means of a nickel pin 0.032 inch in diameter and one and three-quarter inches long. The white disc bears a number and the inscription "Return both discs, C.B.L.," and the red disc contains the inscription "Chesapeake Biological Laboratory, Solomons, Md. Reward. Help appreciated." The tag is put on between the dorsal fins, below the ridge of the back. Procedure for tagging was practically the same as that described by Clark (1934, pp. 14-15), with the exception that we did not use an awl, since the pin itself is sufficiently stiff to punch a hole through the back of the fish. The length of the fish, from tip of the lower jaw to the middle of the forked tail,[2] was measured to the nearest one-half centimeter and recorded on the "scale envelope." A sample of scales was removed from the left side from the place where the tag was to be attached. The whole operation, performed by two men, takes about one minute, and does not weaken the fish appreciably.

The suitability of the type of tags chosen was checked by preliminary observations on rock kept in tanks at the laboratory. The healthy appearance of fish recaptured several months after tagging amply verified the preliminary findings.

The data gathered from tagging experiments are summarized in several tables, and are based only on recaptured fish, tags from which were sent to us, or on information obtained from fish caught and subsequently released. These data are by no means complete, as it is estimated that about 300 tags from fish captured during the winter months with gill nets[3] have not as yet been returned.

General Remarks on Tagging

The greater portion of tagged fish consisted of 2½-year-old fish of the 1934 year class. This brood, during the period under consideration, was exceptionally abundant not only in Chesapeake Bay but along the Atlantic Coast as well (Merriman, 1937). Female fish of this year class did not reach sexual maturity during 1936 and 1937.

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[2]All lengths of rock mentioned throughout the paper were measured as above.

[3]During the winter of 1936-37 certain groups in Maryland advocated prohibition of the use of gill nets. As a result some of the commercial netters became very suspicious of the present work and, consequently, uncooperative.

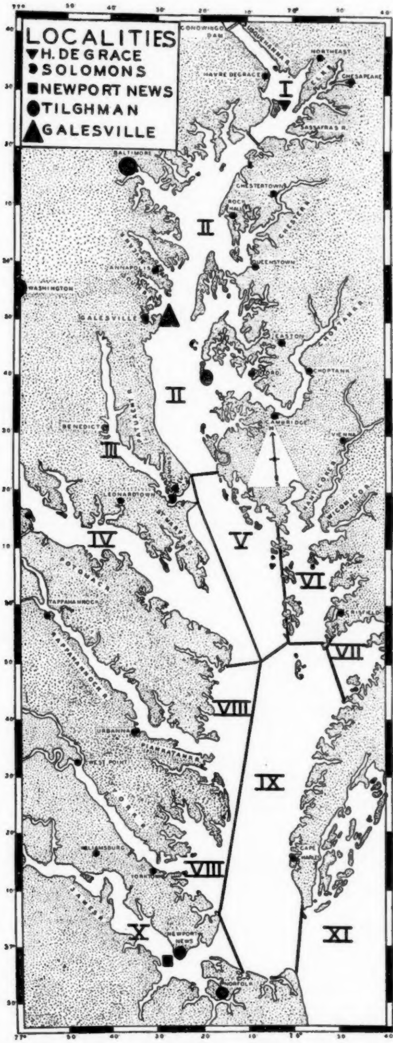

Fig. 1.—Map of Chesapeake Bay showing location of the tagging operations and areas of the recaptures.

Most of the males, however, did reach maturity in the spring of 1937.

The present paper covers nine months of observations within Chesapeake Bay from October 8, 1936, to June 30, 1937, and deals only with general problems of migration; therefore the details of recaptures within small localities will be omitted. The whole region under consideration was subdivided into eleven areas, which differ one from another by their physiographic conditions. Areas I to X are within the bay proper, while Area XI is located outside and embraces the states located northward, from Delaware to Massachusetts. These areas are indicated on the accompanying map (Figure 1). The tags which were recovered from various markets, and for which accurate information was not secured, are grouped under the section "Fish Markets."

The number of returns of tagged fish in general varied with the number of fish tagged (Table 1). The Galesville and Tilghman tagging operations gave the greatest numbers of recaptures. Galesville returns were significantly higher than those of Tilghman, no doubt due to the fact that during the fall[4] and spring months the Galesville fish migrated along the western shore of the bay, where a large number of pound nets are located throughout practically the entire coast from Galesville to the James River, inclusive. Along the eastern shore only a small number of pound nets was fished south of the Tilghman area. Therefore, the fish moving along the western shore are subjected to more intensive fishing by pound nets than those moving along the eastern shore.

The James River (Newport News) tagging operations occupy the next position in the recaptures. The Solomons tagging gives the very small return of only three fish, or 4.5 per cent. The fish at Havre de Grace were tagged in early June, hence only a very short time elapsed from the time of tagging up to the presentation of this paper, seemingly not sufficient time to give conclusions. In the following discussion only fish tagged at Galesville, Tilghman, and Newport News will receive detailed consideration. In view of the fact that fish from these localities behaved differently, it seems advisable to treat them separately.

Galesville School

During October of 1936 all the recaptures from the Galesville school, amounting to 236, or 47.6 per cent of those tagged, were made in Area II, principally around Galesville (Thomas Point and Herring Bay) and Rock Hall, Maryland. Due to the interest of local fishermen, 222 of the recaptured Galesville fish were immediately released during October, and 65 during November.

As an illustration of how stationary the Galesville school was dur-

[4]Throughout the present paper the different seasons are understood as follows: fall embraces September-November; winter includes December-February; spring, March-May; and the remaining months constitute summer.

TABLE 1. DETAILS OF TAGGING OF STRIPED BASS IN CHESAPEAKE BAY, 1936-1937

Locality of tagging	Date of tagging	Number of fish tagged	(Millimeters) Length of range	Method of capture
Havre de Grace, Maryland	June 2-3, 1937	65	215-550	Pound net
Galesville, Maryland	October 8-22, 1936	871	235-555	Pound net
Solomons, Maryland	October 8-November 12, 1936	67	290-445	Hook and line
Tilghman, Maryland	October 25-29, 1936	512	205-450	Pound net
Tilghman, Maryland	March 18-April 20, 1937	6	215-415	Drift gill net
Newport News, Virginia	January 6, 1937	42	230-515	Fyke net
All Collections	October 8, 1936-June 3, 1937	1,563	215-555	

TABLE 2. REGIONAL RECAPTURES OF THE TAGGED FISH DURING THE PERIOD OCTOBER 8, 1936, TO JUNE 30, 1937

Area of recaptures		Tagging localities					
No.	Name	Galesville	Tilghman	Newport News	Total Number	Percentage	Method of capture
I	Susquehanna River	5	4	0	9	1.4	P.N.; D.G.N.*
II	Galesville—Tilghman	375	58	0	433	68.8	P.N.; D.G.N.; S.G.N.; H. & L.
III	Patuxent River	5	0	0	5	0.8	P.N.; S.G.N.
IV	Potomac River	29	8	1	38	6.0	P.N.; S.G.N.
V	Barren Island—Hoopers Island	8	10	0	18	2.8	D.G.N.
VI	Tangier Sound	22	14	0	36	5.7	P.N.; D.G.N.; S.G.N.
VII	Pocomoke Sound	5	3	0	8	1.3	P.N.; D.G.N.
VIII	Rappahannock—York Rivers	12	4	0	16	2.6	P.N.
IX	James River	15	4	13	32	5.2	P.N.; F.N.; D.G.N.
X	Lower Chesapeake	2	0	0	2	0.3	P.N.
XI	Delaware—Massachusetts	9	6	0	15	2.4	P.N.; D.G.N.; H. & L.
	Fish markets	13	4	0	17	2.7	
	Total number of recaptures	500	115	14	629	100.0	

*Abbreviations in Tables 2 and 3 signify:

P.N.—Pound net D.G.N.—Drift gill net S.G.N.—Stake gill net H. & L.—Hook and line

ing that time, several instances of recapture may be quoted. One fish (No. 288) tagged at Galesville on October 13, 1937, was recaptured locally five times during the period from October 17 to November 11. Another fish (No. 195) tagged on October 12, 1937, was recaptured six times in nearby waters from October 14 to November 3. Both of these fish are presumably still alive, as tags from them have not been sent in as yet. Fish No. 121, tagged on October 9, was recaptured locally on October 19 and 22, and finally was killed in James River on March 15, 1937. Fish No. 351, tagged on October 14, was recaptured on October 21 and November 11 at Galesville, and was killed on March 23, 1937, in Tangier Sound. Rock No. 9, tagged on October 8, was recaptured locally eleven days later, and was killed on April 14, 1937, at Point Judith, Rhode Island. All these examples demonstrated that the tagged rock can stand repeated recaptures very well.

As mentioned, during December the principal fishing for rock was done with drift gill nets, and, unfortunately for our studies, the greater number of tags from recaptured fish was kept by local fishermen. We are inclined to believe that the greatest part of the Galesville school vacated Area II during the end of November and the first week of December, and returned there around December 15, after a period of warm weather.

During January, 1937, the distribution of Galesville fish was, on the whole, similar to that of the latter half of December. Some tags were recorded in Areas II and IX. Two fish were taken in the upper Patuxent River, above Benedict (Area III), and two others at the mouth of the Rappahannock River. Throughout February a definite concentration of the Galesville school was noticed in and near Tangier Sound (Areas V and VI), where six fish were recovered. No recaptures were made from other parts of the bay. During the same month a few Galesville fish were taken for the first time outside of Chesapeake Bay in Area XI. The latter recaptures will be dealt with in a separate section.

From February to April a considerable number of rock was taken with stake gill nets. Operators of these nets were cooperative, thus bringing about an increase in recaptures. During the spring months the Galesville fish had a tendency to congregate in areas of low salinity, or even in fresh water. These areas were probably warming up more rapidly than the bay. The chief reason, however, for such concentration was suspected to be the spawning migration of some Galesville fish (males).

The concentration of this school became noticeable in Tangier Sound during February, and even more conspicuous during March, when thirteen fish were taken there. Another concentration was apparent at this time in the upper part of the Potomac River, where ten tags were recovered around Port Tobacco Creek and Maryland Point (upper part of Area IV, not shown on the map). About the

TABLE 3. MONTHLY RECAPTURES OF THE TAGGED FISH IN ALL AREAS

Month	Tagging localities Galesville	Solomons	Tilghman	Newport News	Total number	Percentage	Chief methods of capture
October, 1936	238	0	13	0	251	39.7	P.N.*
November, 1936	120	0	22	0	142	22.5	P.N.
December, 1936	19	0	9	0	28	4.4	D.G.N.; F.N.
January, 1937	11	0	7	2	20	3.2	D.G.N.; S.G.N.
February, 1937	9	2	9	2	22	3.4	S.G.N.; D.G.N.
March, 1937	52	1	20	7	80	12.7	S.G.N.; P.N.
April, 1937	39	0	26	3	68	10.8	S.G.N.; P.N.
May, 1937	8	0	9	0	17	2.7	P.N.
June, 1937	4	0	0	0	4	0.6	P.N.
Total number of recaptures	500	3	115	14	632	100.0	
Percentage	57.4	4.5	22.5	33.4	42.4	100.0	

*For abbreviations, see Table 2.

same number of fish was taken from scattered localities in Area II. Pearson (1933, p. 16) observed in 1932 that one of his tagged fish was recaptured off Maryland Point in the Potomac River on March 17, and another in the Wicomico River a few miles below Salisbury (Area VI) on March 23. Thus fish of the Galesville school in the spring months of 1937 were recaptured principally in the localities where previously they had been demonstrated to migrate.

It is significant that fish were taken again in the James River during March 8-24, although not one return was made from January 15 to February 28 (Table 4).

In April the Galesville fish were taken only in the middle and upper parts of the bay, being completely absent in Areas VIII-X. Some fish were recaptured in the upper Potomac River and in Tangier Sound. The greater number (sixteen), however, was taken in the upper portion of Area II, indicating a journey to the Susquehanna Flats. One fish was recovered at Turkey Point (Area I).

During May and the first week of June, the only recaptures were five fish recovered in Areas II, V, and VIII. The details of the recaptures of Galesville fish in different months and throughout various areas are summarized in Tables 2-5.

Tilghman School

Five hundred and twelve rock were tagged in the Tilghman section, the greater number of which were released during the last week of October. Only a very small number (six) was tagged in the spring of 1937. The following description refers to the fish tagged in October, since not one of the spring tags has yet been returned.

During the first week of November fish of the Tilghman school were recaptured locally and around Galesville. Throughout the remaining part of November some of these joined the Galesville school and migrated southward with them. Six Tilghman fish were taken at Flagpond during November 11-19 (Area II). Two fish were recaptured farther south, off Rappahannock River, on November 17. The Tilghman school appeared in the James River as early as December 14. Two more fish were taken in the James River during December 17-24, and one on January 12 (Table 4).

A difference between Galesville and Tilghman schools can be seen in the fact that the Tilghman fish were taken in the Choptank River, not only during December but also in January. This fact suggests the possibility that some Tilghman fish remain throughout the winter in the deeper holes of the river instead of migrating south. Local fishermen are inclined to believe that the Choptank rock stay locally the whole year. It is regretted that data on the returns for the winter months are too incomplete to warrant more definite conclusions.

The greatest number of Tilghman fish (forty-six) was taken during March and April. These fish were recaptured principally in Tangier Sound and the upper Potomac River (Table 4). From April

TABLE 4. WEEKLY RECAPTURES OF THE GALESVILLE (G.) AND TILGHMAN (T.) TAGGED ROCK IN SEVERAL CHESAPEAKE BAY LOCALITIES DURING WINTER AND SPRING OF 1937

Month	1-8 G.	1-8 T.	1-8 Total	9-16 G.	9-16 T.	9-16 Total	17-24 G.	17-24 T.	17-24 Total	25-31 G.	25-31 T.	25-31 Total	Total G.	Total T.	Total
Upper Potomac River															
March	4	0	4	2	1	3	3	0	3	1	1	2	10	2	12
April	1	2	3	1	0	1	1	0	1	1	0	1	4	2	6
Total	5	2	7	3	1	4	4	0	4	2	1	3	14	4	18
Tangier Sound															
February	0	0	0	1	0	1	1	1	2	0	0	0	2	1	3
March	3	0	3	5	1	6	5	0	5	0	3	3	13	4	17
April	2	3	5	3	3	6	1	1	2	0	0	0	6	7	13
Total	5	3	8	9	4	13	7	2	9	0	3	3	21	12	33
James River															
December	1	0	1	1	1	2	4	2	6	0	0	0	6	3	9
January	1	0	1	0	1	1	0	0	0	0	0	0	1	1	2
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	2	0	2	4	0	4	2	0	2	0	0	0	8	0	8
Total	4	0	4	5	2	7	6	2	8	0	0	0	15	4	19

on, some fish were recovered outside of Chesapeake Bay, while within the bay itself the last fish taken was that caught on May 3, 1937, in the Tred Avon River, a tributary to the Choptank River (Area II).

TABLE 5. SEASONAL RECAPTURES, IN PERCENTAGES, OF GALESVILLE AND TILGHMAN FISH IN PRINCIPAL CHESAPEAKE BAY AREAS

Area	Fall 1936	Winter 1936-1937	Spring 1937	Total number recaptures
II	84.1	4.8	11.1	433
IV	7.0	2.7	70.3	37
VI	0.0	11.0	89.0	36
IX	0.0	63.2	36.8	19

The end of May and the whole of June are the months when fishing activity in Maryland is very low. This fact may be offered as one explanation for the small number of returns for both Galesville and Tilghman schools during the early summer months. Furthermore, after intensive fall and winter fishing, probably not more than one-third of the fish tagged were still alive, a situation that would be reflected in tag returns.

James River School

Forty-two fish were tagged on the James River, off Newport News, on January 6, 1937. Of this number fourteen were recaptured. Thirteen of them were taken from the James River while the remaining one was taken in the upper Potomac River on April 13. The details of monthly recaptures of these fish are summarized in Table 3. These data suggest that James River rock belong to a distinct school of fish which seemingly are non-migratory. One fish recaptured in the Potomac River does not disprove the above statement, since it really could have been a straggler from upper Chesapeake Bay that had been tagged in the James. As was pointed out (Table 4), during December and January numerous Galesville and Tilghman fish were taken from James River. A belief that the James River rock represent a separate school is substantiated by an observation that these fish possess on the average a smaller number of rays in different fins in comparison with fish from the upper Chesapeake Bay. For instance, the number of soft rays in the second dorsal was 11.66 and, in the anal fin, 10.72 in James River fish, whereas rock from Maryland waters possessed 11.93 and 10.93 rays, respectively. These differences proved to be statistically significant.

Recaptures Outside of Chesapeake Bay

Tags taken from fish released as a part of this study were not returned from territory out of the Chesapeake area until after January. On February 1, 1937, the first Galesville fish was taken in the Toms River, New Jersey (Tables 6 and 7). According to the Philadelphia "Evening Bulletin" of February 12, 1937, unusually large catches

TABLE 6. DETAILS OF RECAPTURE OF THE ROCK OUTSIDE OF CHESAPEAKE BAY

Tag No.	Date of tagging, 1936	Place of tagging	Length of fish in millimeters	Date of recapture 1937	Days fish were out	Distance, miles	Place of recapture	Method of capture	Name and address
310	October 14	Galesville	355	February 1	110	370	Toms River, N. J.	Hook & line	F. Kozlowski, Jersey City, N. J.
176	October 12	Galesville	400	March 22	161	270	Cape May, N. J.	Drift net	A. Daley, Philadelphia, Pa.
9	October 8	Galesville	385	April 14	188	570	Pt. Judith, R. I.	Fish trap	R. E. Mann, Narragansett, R. I.
1252	October 28	Tilghman	335	April 22	177	300	Bowers Beach, Del.	? net	W. W. Benner, Bowers, Del.
395	October 14	Galesville	350	April 28	196	570	Pt. Judith, R. I.	Fish trap	T. E. Mann, Narragansett, R. I.
648	October 19	Galesville	355	May 5	199	580	Connecticut R., Conn.	Drift net	J. Ziobron, Moodus, Conn.
1193	October 29	Tilghman	335	May 5	189	600	Newport, R. I.	Pound net	J. F. Mack, Newport, R. I.
1290	October 29	Tilghman	295	May 5	189	600	Newport, R. I.	Pound net	J. F. Mack, Newport, R. I.
630	October 16	Galesville	355	May 10	206	600	Prices Neck, R. I.	Pound net	J. F. Mack, Newport, R. I.
944	October 28	Tilghman	285	May 11	195	580	Connecticut R., Conn.	Gill net	E. E. Heiney, Saybrook Pt., Conn.
1295	October 28	Tilghman	205	May 24	208	570	Pt. Judith, R. I.	Fish trap	W. E. Clark, Wakefield, R. I.
1002	October 28	Tilghman	330	May 27	211	600	Mt. Hope Bay, Mass.	Hook & line	D. Birchall, Central Falls, R. I.
28	October 8	Galesville	395	June 3	236	900	Cape Ann, Mass.	Fish trap	G. L. Davis, Gloucester, Mass.
642	October 19	Galesville	335	June 4	224	570	Connecticut R., Conn.	Drift net	J. Ziobron, Moodus, Conn.
329	October 14	Galesville	385	June 30	258	850	Saddle Rock, Mass.	----------	R. A. Woodbury, Gl'c'st'r, Mass.
962	October 28	Tilghman	375	August 2	278	820	Barnstable Bay, Mass.	Mackerel seine	Capt. Favazza, Gloucester, Mass.
703	October 21	Galesville	365	September 1	345	600	Buzzards Bay, Mass.	?	S. Cahoon, Woods Hole, Mass.
966	October 28	Tilghman	425	September 13	350	450	Newark, N. J.	?	Municipal Fish Co., Newark, N. J.

of the striped bass were made during February in this river by snagging the fish with unbaited hooks. The paper stated that "about 4,000 have been caught in three days in a river hole a mile up the Toms River from here opposite the Cranmore County Club, and many more are expected to be pulled up before the supply gives out. The fish are all males. . . . Individual catches run as high as 600 pounds, the fish ranging in weight from 2 to 20 pounds each. The hole from which they are being pulled up is about 40 feet deep and 100 feet square. The catch so far is already far ahead of the entire 1933 total for the New Jersey coast. The fish are here two months ahead of schedule, due to unseasonable warmth."

The data for outside recaptures arc summarized in Tables 6 and 7. It is evident that during 1937, from February to May, there was a definite northern movement of a limited number of Galesville and Tilghman fish along the Atlantic coast from Delaware to Massachusetts. Through June to September these Chesapeake fish stayed along the New England coast, principally in the southern part of the Gulf of Maine. During October, 1937, they undertook a southward migration. On October 1, 1937, a Galesville fish (No. 703) was taken south from Cape Cod in Buzzard's Bay, Massachusetts, and another Tilghman tag (No. 966) was recovered from a Newark, New Jersey, fish market on October 13, 1937, being reported from local waters. It is indicated, on the basis of returns, that the Chesapeake fish passed to and from the Gulf of Maine through the Cape Cod channel but not around Cape Cod (Table 6).

It is important to note here that Merriman (1937) has done considerable tagging of striped bass in Connecticut. Of special interest are five which were tagged in the Niantic River during August 27 to September 29, 1936. Two of these fish were taken at the entrance to Chesapeake Bay, off Cape Charles, one on December 14 and the other on December 28, 1936. One more was caught on May 17, 1937, off Plantation Creek, Cape Charles, Virginia. Two other fish were taken within the bay, one on March 19, 1937, in the Wicomico River, Tan-

TABLE 7. MONTHLY RECAPTURES OF GALESVILLE AND TILGHMAN FISH OUTSIDE OF CHESAPEAKE BAY DURING 1937

State	February	March	April	May	June	July	August	September	October	Total
Delaware	0	0	1	0	0	0	0	0	0	1
New Jersey	1	1	0	0	0	0	0	0	1	3
Connecticut	0	0	0	2	1	0	0	0	0	3
Rhode Island	0	0	2	4	0	0	0	0	0	6
Massachusetts	0	0	0	1	2	0	1	0	1	5
Total number of recaptures	1	1	3	7	3	0	1	0	2	18

gier Sound (Area VI), and the other on May 3, 1937, in the Wye River, Eastern Bay (Area II). All of Merriman's fish in question ranged from 360 to 430 millimeters, a size which is directly comparable with our fish recaptured outside of the bay.

Comparison of Returns from Striped Bass Tagged in Different Regions

The tagging of striped bass was started in 1931, when a few fish were tagged by Pearson (1933) in upper Chesapeake Bay. One year later Clark (1934) began similar tagging in California. The results of tagging by these and subsequent workers are summarized in Table 8. It is rather surprising that in California tagging investigations of striped bass only 10 per cent were recaptured during a period longer than three years (Table 8).

TABLE 8. COMPARISON OF RETURNS OF THE ROCK TAGGED IN DIFFERENT REGIONS

Date	Region of tagging	Number of fish tagged	Fish recaptured Number	Percentage	Period, months	Authority
July-Aug., 1931	Chesapeake Bay	305	86	28.2	12	Pearson, 1933
Oct. 8, 1936-June 3, 1937	Chesapeake Bay	1,563	632	42.4	9	Vladykov and Wallace, 1938
April-Oct., 1936	Connecticut	1,397	260	18.5	9	Merriman, 1937
Sept. 20, 1932-Oct. 24, 1935	California	1,544	151	9.8	39	Clark, 1936

The returns from the 1936 Chesapeake tagging were higher than in any other similar experiments (Table 8). During the period of nine months 632 recaptures, or 42.4 per cent, were made. To this number should be added at least 300 tags which have not been turned in. All these data, although indicating a very intensive fishing in Chesapeake Bay, are by no means conclusive as to the percentage of the rock population removed by the fishery within the bay, since the ratio of tagged fish to unmarked was unknown.

It is of interest to note here that Clark (1936, p. 274) concluded that "there is no relation between the size of the fish when tagged and the distance traveled, or between size and elapsed time before recapture. . . . A study of the bass tagged and recovered so far indicates no definite migration, simply a diffusion from the locality in which the bass were tagged." Thus, the striped bass along the Pacific Coast behaved quite differently from the fish along the At-

lantic Coast, where, for instance, some Chesapeake Bay fish have traveled as far as 900 miles in a period of about nine months (Table 6). Actually this travel was accomplished in far less time since, according to returns, fish did not leave the bay until mid-winter. Individual records show as many as 60 miles traveled in a single day.

Discussion

Observations which were made on rock apart from tagging throw added light on the movements of the fish and may be correlated and interpreted along with the records that have accrued from tagging.

Movements within Chesapeake Bay. The striped bass in Chesapeake Bay undertake regular movements within the bay, which are evident, first of all, from fluctuations in commercial fishing. Every spring, from the end of February to the end of April, a certain number of large rock, often called "cow rock," ranging in weight from 8 to 70 pounds, are taken by Chesapeake Bay fishermen in pound nets fished for shad (*Alosa sapidissima*) and alewife (*Pomolobus*). Together with these "cow rock," smaller fish are taken. In addition to pound nets, a certain number of stake gill nets, located close to the shore in very shallow water, are employed. Spring fishing for rock is usually of minor importance, but during 1937 very good catches were made.

From June to the middle of September rock are taken only occasionally in pound nets, although during the summer months of 1936 and 1937 exceptionally large numbers of rock were observed schooling throughout the entire upper and middle Chesapeake Bay. These fish were very attractive to anglers. The principal method of sport fishing is trolling. "Barracuda feather" is considered the best lure. During the summer months the most profitable commercial method of fishing is haul seining, and very large catches are occasionally made. During the period under consideration, the best catch, to our knowledge, was that made on July 22, 1936, in Chesapeake Bay at Cedar Point, when 16,000 pounds of rock were taken in a single haul of a 120-fathom seine.

After the first northern storms, the rock, schooling near the surface in open parts of the bay, start to approach close to the shore and then constitute the principal catch in pound nets. The best catches during 1936 were made from the middle of October to the last week of November. An example may be cited in the catch of 5,000 pounds of rock in a single pound net on October 29, 1936, at Tilghman.

Variations in the amount of rock taken in different pound nets located along Chesapeake Bay clearly indicate shifting of schools during the fall from north to south, principally along the western shore of the bay. The general trend of increasing catches in a southward direction is practically the same as has been shown by the tag returns from the Galesville school.

From about the middle of December until the first week of February, rock are taken with gill nets in Chesapeake Bay in considerable amounts, although less than those obtained with pound nets during the fall. The best catch to our knowledge was 4,600 pounds of rock taken in a single fishing with a gill net 1,000 feet long during the winter of 1936. The best localities for gill netting are usually the deeper parts of the bay, from Hooper Island to Barren Island. However, during the winter of 1936, which was very mild and without formation of ice, rock were taken with gill nets in rather shallow water.

What is the reason for movements of rock from the upper to the lower bay in the fall months, and the reverse direction during spring? The temperature of the water, as such, probably does not affect to any great extent the striped bass, as these fish can well stand very low temperatures, as is suggested by their geographical distribution and by direct observations. The variation in salinity of the water is also probably not the cause, as the rock is a very tolerant species. One of the reasons which seems outstanding is the food factor. An investigation based on about 2,500 stomachs of rock (Vladykov and Hollis, MS.) indicated a definite seasonal variation in food. The choice foods of the Chesapeake rock during the summer months were menhaden (*Brevoortia tyrannus*) and anchovy (*Anchoviella mitchilli*). During the late fall and winter months these food species were almost completely absent from the rock diet in Maryland waters, and were replaced by young spot (*Leiostomus xanthurus*) and croaker (*Micropogen undulatus*). From about the middle of October the anchovy, locally known as "silver side," "shiner," or "hopper," and the menhaden, "bunker," or "alewife" migrate southward. The rock, pursuing these food species, go to the lower Chesapeake Bay. This pursuit no doubt is the reason for the movement of the Galesville and Tilghman fish to the James River during the winter of 1936. In the stomachs of rock from the James River, obtained during December and January, menhaden and anchovy occurred in abundance. On the other hand, the anchovy was completely absent in stomachs of rock from Maryland during that season and the menhaden was represented by very small numbers, less than 4 per cent of the total food. The return of rock from the James River to the upper bay during warm periods in the winter months could be explained on the supposition that they were pursuing either menhaden or, more probably, young croakers. Supporting evidence appears from stomach analyses.

The distribution of tagged fish during the spring months, from the end of February to the end of April, in the upper parts of the Potomac River and in Tangier Sound, was probably due to concentration for spawning purposes, as was demonstrated by gonad analysis of fish taken by means of stake gill nets.

Distant migration. Eighteen of the fish tagged in 1936 were re-

captured the following summer outside of Chesapeake Bay, in several North Atlantic states (Tables 6 and 7), while five Connecticut rock during their southward migration were recovered within the Chesapeake region. Are these recaptures sufficient evidence to make definite conclusions that the Chesapeake Bay rock is a migratory fish which vacates the bay in considerable numbers and visits the northern Atlantic states during the summer months? Merriman (1937, pp. 30-31) expressed such a possibility. His reasons were based on tagging results and other observations that disclosed in 1936 an exceptionally large number of 2-year-old rock present in Connecticut. The 1934 year class was also extremely abundant in Chesapeake Bay, a condition noticed in 1935. Merriman was unable to secure in Connecticut any definite informaion about young rock of sizes comparable to those of Chesapeake Bay in 1935. He attributed the absence of young rock in Connecticut to heavy pollutions of local rivers, which makes spawning impossible. He was then forced to the conclusion that Connecticut receives its fish from other bodies of water: "The fish two years old are probably the youngest to take any large part in the migrations." The present investigations give support to his findings that fish younger than 2 years do not undertake extensive migrations. We observed, for instance, that the 1936 year class was present in Chesapeake Bay in several rivers (Choptank, Patuxent, etc.), not only during the summer and fall months of 1936, but also during March and April of 1937. Moreover, the greater number of rock tagged by us in 1936 were fish of the 1934 year class (with two annuli)—fish about 2½ years old when tagged. All these observations seemingly corroborate Merriman's belief that the abundance of rock in Connecticut during the summer of 1936 "had as its point of origin the Chesapeake Bay area." Only further and more extensive tagging of Chesapeake rock of different sizes, especially yearlings, can definitely settle this very important question. The racial studies of rock populations from different localities along the Atlantic Coast will be of great help in the final analysis.

It is important here to point out facts in opposition to the belief that the Chesapeake Bay rock is migratory. First of all the outside recaptures of the Chesapeake tagged fish represented only a very small number, or approximately 2.5 per cent of the total recaptures. The Connecticut tagged fish recovered from Chesapeake Bay represent even a smaller amount, less than 2.0 per cent of Merriman's total recaptures (Table 8).

Tags from fish marked under the direction of the Chesapeake Biological Laboratory, and taken from bodies of water foreign to the Chesapeake, were returned promptly and very cooperatively. Perhaps all such tags recovered from fish caught outside of Chesapeake Bay were returned. If so, it is highly improbable that very large catches of rock made in different Atlantic states, from North Carolina to Maine inclusive, during 1936 and 1937, should be attributed

to Chesapeake Bay fish. Evidence brought by Merriman that a large portion of the Connecticut rock was composed of the 1934 year class, which is equally abundant in Chesapeake Bay, is merely circumstantial. There is the possibility that the very prolific 1934 brood had its origin in different regions independently, due to favorable conditions for development and survival throughout the range. In Maine, for instance, according to the "Baltimore Sunday Sun" of June 6, 1937, "large schools of two to four pound striped bass are again running up Maine rivers. . . . Fishermen were surprised last year, soon after the flood, when the bass resumed their runs to inland spawning beds, after a lapse of many years. Commissioner George J. Stobie, of the Maine Department of Inland Fisheries and Game, attributed the reappearance of the fish to the cleansing of the rivers by the flood.[5] He predicted at that time that so long as the rivers remained unpolluted the spiny-finned fish would continue their annual trips into Maine waters. The Penobscot, Sheepscot and Saco rivers, to name a few, are teeming with the fish, which are expected to continue their runs for several weeks." Commissioner Stobie's observations are supported by the fact that not one Maryland or Virginia tagged fish was recaptured in Maine, as was also true for the Connecticut tagged fish. These facts indicate the independence of the Maine population. Rock were likewise abundant in Massachusetts, according to Mr. F. E. Firth, biological collector for the U. S. Bureau of Fisheries at Boston. Mr. Firth, in his letter of August 3, 1937, stated that Capt. Favazza took our fish No. 962 along with 11,000 pounds of rock in the same haul made in Barnstable Bay on August 1, 1937. Another fisherman, in the same locality and on the same day, caught 7,000 pounds of rock ranging in size from 1½ to 20 pounds each. In spite of the very large catches in Massachusetts, only five Chesapeake Bay tags were recovered. At Point Judith, Rhode Island, during the summer of 1937, catches comparable to those of the more northern states were made, with the recovery of only six Chesapeake tags. In New Jersey, as has already been pointed out, exceptional catches were made in Toms River during February, 1937, when one Chesapeake tag was recovered. It is very improbable that abundance of rock in North Carolina waters is due to migration from Chesapeake Bay, since not a single Chesapeake tag has been taken from more southerly waters.

Even if abundance of the 1934 brood in southern New England is due to migration from the abundant stock of young in Chesapeake Bay, it is certain that this migration is of little importance to conservationists in the Chesapeake Bay area. It is probable that only a small proportion of the young desert the bay, as evidenced by the

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[5]This may be equally true of more southern Atlantic states. Within Chesapeake Bay, for instance, unusually stormy weather during August, 1933 (Annual Report, Maryland Conservation Department, 1933) and a subsequent severe winter with heavy spring freshets may be a possible factor responsible for the production of the outstanding 1934 brood.

continued great abundance of this brood in the commercial and sport catches in the Chesapeake during 1936 and 1937. Moreover, the catch, and presumably the abundance of rock, is much less in New York and southern New England than in Chesapeake Bay.

Differences in the movements of tagged fish from the two centers of investigation were quite noticeable. Not one of the Connecticut tagged fish was recaptured north of Cape Cod, and not one of the Chesapeake tagged fish was recovered south of Chesapeake Bay. In other words, the Connecticut fish range farther south, extending from Connecticut to North Carolina, while the range of Chesapeake rock is more northern, extending up to Massachusetts. The principal overlapping occurs in New Jersey and New York. From the New Jersey territory further evidence of spawning and distribution was obtained by Corson (1926) who, from his work, was inclined to believe that rock migrate from New Jersey to North Carolina. The presence of young rock of the 1936 season in the Hudson River, New York, was demonstrated by collections made by the New York State Conservation Department.[6] Such evidence as that from New Jersey and New York indicates that rock may have their origin over a wider territory than the Chesapeake Bay or even North Carolina waters.

Summarizing the above information, there are grounds for believing that the rock population in Connecticut may be composed of fish of different origins and not made up exclusively of Chesapeake fish as Merriman believed. It is possible that the striped bass population of southern New England is principally composed of the New York, New Jersey, and North Carolina fish, while Chesapeake rock are represented by comparatively small numbers in that territory. It may also be true that during the fall, winter, and early spring some fish from the Gulf of Maine may occur in the same region. On the other hand, there is as yet no evidence that the rock population of Chesapeake Bay, although consisting of several different schools (James River, Upper Bay, etc.) receives any contributions from spawning in other Atlantic areas. Recaptures there of a certain number of rock tagged in Connecticut merely suggests that Chesapeake stragglers, having migrated to the north during the spring months, returned to their native region during the following winter or spring.

In order to find some explanation for the extent of migration of a part of the Chesapeake fish, we turn to the food factor. Previous to February, 1937, not one tagged specimen was recaptured from outside of the bay, the James River being the most distant locality visited by the fish up to that time. This river had a variety of different food species preferred by the Chesapeake rock. Later on, the greater part of the tagged fish vacated the James River (Table 4), and returned to Maryland waters, pursuing anchovy and menhaden (Vlady-

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[6]Personal communication from Dr. John R. Greeley, New York State Conservation Department, Albany, New York, in letter of October 23, 1936.

kov and Hollis, MS.) which began to ascend the upper bay. It seems probable that at this time a small number of rock may have branched off from the main body and, instead of running toward the head of Chesapeake Bay, may have gone northward along the Atlantic coast. The definite reason for such action remains undiscovered, but it is not improbable that they were following some kind of food northward.

The question asked in the title of this paper, "Is the striped bass of Chesapeake Bay a migratory fish?" may be quite definitely answered in the negative. On the basis of tagging experiments during 1936, it was established that only a very small number of the Chesapeake fish, more than 2 years old, leave the bay, while the greater part of the population does not move to other bodies of water.

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Field work was facilitated, during the tagging operations, by fish dealers and fishermen. Among them the names of Woodfield Brothers, Galesville, and George T. Harrison, Tilghman, should be mentioned. The pound netters, Captains Bernard Hallock, Noah and Warren Hazard of Galesville, and Bane Bradshaw, Carroll Jackson, and Nathan Parks of Tilghman offered every possible assistance for tagging fish from their nets. Captain Harvey Mister, of the Maryland Conservation Department's staff, aided materially in the progress of the work around Solomons. Mr. Albert Powell, in charge of the Maryland Conservation Department's fish hatcheries, aided by members of his staff, helped greatly with the field work during certain periods. The sportsmen of the Chesapeake territory, too, showed much interest and cooperation in furthering this study, which in no small part was initiated at their behest.

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FISH CULTURE—PAST AND FUTURE

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ABSTRACT

Belief in a general depletion of the virgin stocks of fish, and enthusiasm over the new procedure of hatching fish eggs and planting the fry that arose in the sixties of the last century served as powerful stimuli to the development of fishery services and the initiation of scientific study of the fisheries in both the United States and Canada. The early fish culturists were the persons who started this Society in 1870. The peak of the development of the early simple fish culture was reached about the turn of the century, since which time there has been retrenchment as well as attempts both to determine what practice is effective and to develop methods that will ensure the desired results.

Many fish, such as the Atlantic salmon that spends part of its life in the sea, are susceptible only to partial fish culture. That fish, as studied in the Maritime Provinces of Canada and particularly in the Margaree River, is available in the river in the adult stage depending upon variable forces, principally stream flow, which may have to be controlled to assure angling. Control of stream flow seems also necessary to prevent mortality in speckled trout by bringing them from a shallow lake into cold brooks before the water becomes too warm in summer, and to prevent mortality in spawning gaspereaux by bringing them up from the tidal waters of a shallow estuary which exposes them to great changes in salinity. Control of kingfishers and mergansers on streams inhabited by young salmon seems definitely indicated as the most important measure for maintaining the stock of salmon at a high level. The traditional fish culture may be made effective by a scientific distribution of the young salmon to suit very local conditions. Possibilities also exist for increasing the salmon stock by stream improvement, which may be effective when the requirements of the young salmon are adequately known and when procedure has been accurately tested.

Fish culture was the foundation on which our Society was built and it has continued to be the matter of principal interest to us. Its ever-changing present situation is very much with us in a great variety of papers, but certain aspects of the past tend to be forgotten. Of the unknown, problematical future we would wish to have a clear vision, to which what seem like real possibilities may prove to be reliable guides.

During the sixties of the last century the procedure for procuring, fertilizing and hatching the eggs of salmonids was developed more or less independently by several persons in the eastern part of the continent. This is the typical fish culture which has been continued for more than two generations and which is carried on at what are known as fish hatcheries. While not limited to this continent, the practise developed most rapidly and attained its fullest use in North America.

Perhaps the chief reason for this development lay in the circumstances of a population rapidly increasing under new conditions. What were considered virgin lands and virgin waters were being ex-

ploited with increasing intensity and the results were all too evident to be endured without complaint, particularly by individuals with personal knowledge of conditions before as well as those after the increased exploitation. "Exhaustion of the fisheries" became a very general cry. Whether there was an actual decrease in the stock or whether it was the same stock divided among so many that each share became very small, the available facts do not show.

That fear of depletion was the main cause for the extensive adoption of fish culture is well shown by the origin and development of what is now the United States Bureau of Fisheries. On February 9, 1871 the House of Representatives adopted a "joint resolution for the protection and preservation of the food fishes of the coast of the United States" on the basis that "most valuable food fishes" were "rapidly diminishing in numbers." The course proposed was for the "President to appoint a Commissioner of Fish and Fisheries" and Spencer F. Baird of the Smithsonian Institution was the first appointee. The newly appointed Commissioner instituted a thorough enquiry into the causes of the presumed decrease in abundance of the food fishes and an account of the results formed his first report. On February 7, 1872, our Society, organized a little more than a year previously as the American Fish Culturists' Association, "suggested that measures be taken to induce the United States to take part in the great undertaking of introducing or multiplying shad, salmon and other valuable food fishes." This suggestion was so well received that articles on the propagation of food fishes formed the great bulk of the second report of the Commissioner. The work of attempting to remedy a presumed depletion of the fisheries by hatching the eggs and planting the young fish developed rapidly and perhaps reached its culminating point about the end of the century. The Twenty-third Report of the United States Fish Commission, published in 1898, contained a 340-page "Manual of Fish Culture," which dealt with a great variety of fishes and other aquatic animals.

Canada, with a federal fisheries service already in operation, assisted or took over the new practice of fish culture in the late sixties, practically from its inception, and developed a Fish Culture Division, which has continued to this day. In Canada also, belief that the fisheries had been depleted and enthusiasm over the new system of fish culture, which would remedy the depletion, were powerful forces. On the one hand they were responsible for the appointment in 1893 as Commissioner of Fisheries, of a scientist, the late Prof. E. E. Prince, who had specialized in the investigation of fish development. On the other hand they gave rise to a movement, to which the Biological Board of Canada owes its origin, for the establishment of a Marine Biological Station, the chief function of which, as given by Dr. Moses Harvey of Newfoundland in his paper on the subject to the Royal Society of Canada in 1892, was to be

the extension of fish culture to marine forms of life, following in the steps of Professor Baird.

Our Society definitely owes its origin to the enthusiasts who developed fish culture. At its first meeting in the city of New York on December 20, 1870, the Constitution was adopted, Article I of which stated: "The name of this society shall be 'The American Fish Culturists' Association'; Its objects shall be to promote the cause of Fish Culture; to gather and diffuse information bearing upon its practical success; the interchange of friendly feeling and intercourse among the members of the Association; the uniting and encouraging of the individual interests of Fish Culturists." The Society broadened in scope so that in 1878 there was added to Article I, "and the treatment of all questions regarding fish of a scientific and economic character." Finally in 1884 the name was changed to "American Fisheries Society," since "the aims of this Association have gradually become more expanded and elevated—embracing everything that pertains to food fishes in all their manifold relations" (Hon. R. G. Pike). However, most of the papers presented to this Society are still definitely related to fish culture and many of the others have the improvement of fish culture as their objective. No other subject even approaches it in importance.

During the first generation after the inception of fish culture, the simple process of hatching the eggs and planting the young developed rapidly and was extended to one species after another. During the second generation, however, doubts began to arise concerning its effectiveness as a panacea for all the many ills of the fisheries. Instead of extension, the culture of some of the less easily managed fishes was dropped and attempts began to be made to determine accurately the results of fish cultural procedure. At the same time the technique of rearing some of the species to a more or less advanced stage was developing. Steady progress has been and is being made in varied culture where the fish are kept under practically continuous observation and control, and we may confidently predict that this procedure will develop with even greater rapidity in the future.

Nevertheless, the bulk of the fish cultural operations, particularly in Canada, continues to be of the sort that is based upon hope, with no real knowledge of the outcome, since the product is placed in natural waters where observation and control are difficult or impossible. The salmonids form the mainstay of these operations, and among them the Atlantic salmon (*Salmo salar*) has figured prominently from the beginning. Samuel Wilmot, who was the principal person to initiate fish culture in Canada and a member of this Society, began his work at Newcastle, Ontario, in 1866 by attempting to restore this fish to its previous abundance in streams flowing into Lake Ontario, where it was still to be found at that time. The salmon disappeared from those streams in spite of his efforts and has never returned. In contrast, it has remained in the streams and lakes of

Quebec and of the Maritime Provinces, and continues to be there the subject of extensive fish cultural operations. Since the Atlantic salmon reaches its fullest and best form when it feeds and grows in the sea, we cannot expect ever to keep it under full observation and control. It is, therefore, a suitable species to use in considering future possibilities of partial fish culture, that is culture in which the operations cover only part of the life history of the fish.

From this standpoint and with the cooperation of a number of other investigators, notably Mr. H. C. White, I have during recent years been studying this species as it occurs in the Maritime Provinces of Canada and particularly in the Margaree River System of Cape Breton Island. It seems to me that the outlook for the future is quite bright. It must not be thought, however, that the traditional fish culture has been effective in the way claimed by its originators. Data for nearly seventy years, including years before as well as years after the development of fish cultural procedure, fail to show that artificial propagation has cured the conditions of which complaint was made. Now, we can see that no matter how efficiently the procedure may be carried out, and it is carried out most efficiently, those conditions have causes which it cannot touch, causes which call for other measures.

While the salmon enter the Margaree River by spawning time in October in reasonably large numbers regularly every year, not infrequently very few enter early enough in the summer season to provide satisfactory angling in the river. The low temperature of the sea on that coast during the winter and the spring until June very evidently keeps them from being active enough to enter before June. Thereafter, lack of sufficient volume of river water to make a strong influence at sea and lack of sufficiently pronounced freshets may result in few or no salmon entering the estuary and ascending above the head of tide. Knowledge of the hydrography of the neighbouring sea, detailed records of the catches of the nets on the coast, records of the angling catch for each month for twelve seasons, for each week for three seasons and for each day for one season, and daily records of the discharge of each of the two main branches of the river for over twenty years have made it possible to reach these definite conclusions. Control of the water to provide satisfactory volume and sufficiently pronounced freshets at suitable times seems the only remedy that has any likelihood of being effective. The planning of efficient economic control of river flow can come only with more adequate knowledge of the hydrography of the estuary and of the neighbouring sea, and with detailed knowledge of the virtually unexplored field of the behavior of the salmon in relation to the complexity of factors (variable current, light, water solutes, etc.) that determines its movements. Progress in this matter can be speeded up by practical experiments.

Control of stream flow is, or may be, of great importance, not only

for the salmon, but for all fishes that use the streams. In the Margaree River System there are at times rather heavy mortalities in two other fishes, and these mortalities seem to be the result of inadequate stream flow. During the summer the speckled trout (*Salvelinus fontinalis*) passes in large numbers, sometimes in thousands, from Lake Ainslie into the lower still portions of certain cold-water brooks. The individuals are sluggish, apparently because the lake water warms to the very level bottom, reaching a temperature of over 20° C. They are or become infested with lice (*Argulus canadensis* Wilson), which may remove so much of the epithelium of the skin that fungus (*Saprolegnia*) develops and death results. Death depends apparently not only upon the extent of the infestation with the lice, but also upon the degree of lowering of the vitality of the fish by the warm water of the lake and upon the time required for recovery in the brook. It would seem that the condition can be rectified by making sure that the fish enter the brooks (as they sometimes do) early in the season before the lake becomes too warm. Their entrance is clearly governed by stream flow.

The gaspereau (*Pomolobus pseudoharengus*) breeds in Lake Ainslie and other lakes, and feeds and grows in the sea from early in its first year onwards, not maturing before its third year. It uses the river merely for passage between lakes and sea. It has been excessively abundant in recent years, possibly because there is now virtually no market for it and its use is merely local. It passes from the sea up to the lakes in spring or early summer. In the relatively dry spring seasons of 1936 and 1937 the unspawned, mature fish died in such numbers in the estuary, and even for several miles above the head of tide, as to threaten to become a public nuisance, in spite of the fact that gulls had congregated in thousands to feed upon the moribund fish. No parasite could be discovered, but the very watery condition of the blood in many of the dying fish agrees with the conception that individuals that failed to ascend the river, owing to lack of suitable stream conditions, were damaged by passing repeatedly between sea and fresh water. The estuary is very fresh and so shallow that the ebbing tide can carry many individuals out to sea, as has been observed.

It is quite important to have knowledge of the stock of the fish and of the fluctuations in this stock from year to year. Adequate knowledge of the stock of the salmon of a particular river is very difficult to acquire. The fish live in the sea, from which many do not return, and their numbers may be augmented by individuals from other rivers. Nevertheless, the catches of the nets which have been operated on the Margaree Coast for very many years with fair regularity, do appear to give a good idea of the fluctuations in the stock, and the catches of the nets coupled with the tagging and reliberation of some of the fish at the beginning of the season do provide the basis for a rough calculation of the size of the stock.

Since nearly the whole of the net catch is sold for shipment, and records of sales need to be kept, reliable production data are available. Obviously the same is not true for the records of the angling catch, since even the bulk of the fish taken from the river may be carried away without any report; yet the records have comparative value. As for the fish that are poached and those that remain for spawning (few spawn a second time), nothing of much value with respect to their numbers is available or to be expected, unless it should prove feasible to trap the salmon as they enter the river, which operation would give the total entering. Fortunately the tagged fish soon scatter amongst the stock of fish along the coast so that they form a quite constant percentage of the fish taken thereafter by the nets. On the basis of recaptures it has been estimated that in 1935 the Margaree stock of salmon consisted of around 20,000 fish, of which the netters took about 4,000 and the anglers about 2,000. The remainder not only proved sufficient for hatchery purposes, but also served for widespread natural spawning throughout the river system.

Fluctuations in the Margaree stock of salmon from year to year have been at times very pronounced, as shown by the records of net catches. In a study of the salmon statistics of the Maritime region in 1931 it was observed that there had been a periodical scarcity on the average every 9.6 years. Local differences in the year of chief scarcity formed the basis for a prediction that the unknown cause operated on the young in fresh water before they descended as smolts to the sea. The principal cause of decrease in their numbers at this stage has now been fairly clearly shown to be their removal by kingfishers and mergansers, which rear their young on salmon streams. The low, clear condition of the streams in dry seasons facilitates this removal. The records of rainfall and river discharge indicate whether or not the water was low—making the young salmon more available to the birds. These records show that the proper seasons were dry to account for pronounced scarcities of salmon in the past. Control of the birds and control of the water flow are thus indicated as of prime importance for rearing streams, if the stock of salmon is to be maintained at a high level.

It should be obvious that hatching of the eggs and planting of the young salmon can have no effect of value if the planted young are merely added to a native stock which the birds will reduce to a level at which their efforts yield too poor returns to be continued. It would appear that, if the traditional fish culture is to be effective, planting will have to be based upon the results of careful scientific investigation, and the conditions in nature are so complex that continued scientific supervision will probably be necessary. Trapping and counting the young salmon during descent at the smolt stage provide an accurate method of testing for any particular set of natural conditions the efficacy of a definite fish-cultural procedure. The varied conditions encountered throughout the Margaree

System suggest many possibilities, which need to be explored: (a) the control of fish enemies, chiefly eels, which are numerous in certain localities; (b) planting fry in waters where the adults do not spawn and to which the young do not migrate; (c) stocking these waters at the right time and with the proper numbers and sizes of young to suit the local conditions as to (1) area for each set of conditions that may be available, (2) nature and variability of the flow, (3) nature and extent of the cover for protection, (4) temperature of the water, and (5) nature and amount of the food organisms available; (d) the provision of material for spawning beds where it is absent or insufficient and where stream flow will keep it in suitable condition; (e) the provision of more suitable conditions for the young salmon in its various stages as regards stream flow, cover, etc.; and (f) the provision similarly of more suitable conditions for the food organisms, including conditions of light and bottom.

The general desire to get something practical done quickly may result in the future as in the past in an attractive procedure being widely adopted even before there has been any proof of its effectiveness and definitely before the conditions under which it is effective have been properly determined. Persons enthusiastic for a certain procedure or technique and very optimistic as to its value press today for its adoption as others like them did in the past. It is unfortunate if premature action is taken by those rushing to be first in the field. Not only may a good procedure fall into disrepute, but there may be large expenditures without adequate results and a permanent service may be built up on an insecure foundation, making the future of its personnel very precarious.

With this danger in mind, we can look forward with confidence to a fish culture of the future that shall be effective in increasing the numbers of valuable fish available in natural or "wild" waters, as contrasted with those under steady observation and control. It will come only if we approximate the methods used for the latter, particularly in definitely ascertaining the results of any given procedure. The fish culture of the future would seem to involve more or less control of the volume and nature of the water, control of the enemies and possibly of the parasites of the fish, and modification of the conditions generally, and in this we should proceed by slow, sure stages, taking the most feasible as well as the most desired course first. In short we should follow the general principles which through countless generations have served in the development of varied types of land culture. The difficulties of this fish culture are, however, such that scientists must be relied upon to a great extent and they must be in very close touch with or even engaged in practical operations, as in the medical profession.

THE MANAGEMENT OF FISH HATCHERIES IN MEXICO

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We are still in an embryonic state, in all that relates to cultivation, propagation, and distribution of useful fishes in the interior waters of our country. Our rivers, lakes, and in general all our interior waters, especially those of the high plateaus, are poorly populated by good species and these in the majority are declining and degenerating, and thus they should be replaced by better species.

The larger part of our population, particularly the peasant class, has an exceedingly poor diet. These people rarely eat meat, and they consider fish to be a real luxury which is eaten only once or twice a year on the occasion of religious festivals.

Little or nothing had been done by previous administrations regarding practical fish culture in our country. A few private individuals started hatcheries for the breeding of useful fishes, but not for the purpose of propagation and distribution, but to obtain the profits from the sale of the fish in the nearby cities as an article of luxury among the well-to-do classes who pay prohibitive prices for them. A hatchery located on one of the tributaries that feeds the Lerma River, gave me the idea of establishing hatcheries on other tributaries that would permit the restocking of the river with the species of rainbow trout that had been hatched at the first station. This restocking was not to be for commercial purposes, but to repopulate the river and thus fill some twenty pure and cold water rivers and creeks, tributaries of the Lerma River, with trout. This extensive zone in a short time will not only produce enough trout to feed the population living around the river banks but will help to lower the tremendously high prices at which the present producers sell. This is the mission given to our first fish culture station of the Almoloya River. It was at the beginning of last year, that I suggested to our worthy Chief Ingeniero, Migual A. de Quevedo, that a small laboratory be built at this very same place, and after some difficulties I have succeeded at this time in putting it to work, although not at full capacity. At next October's spawning I shall endeavour to bring from the United States sufficient eggs to enter into full activities. In this hatchery we have today as an experiment some 60,000 trout that have reached a size of 15 centimeters (6 inches), which demonstrate that the species can live perfectly under the conditions of these waters.

Very soon in another suitable place, we shall begin the construction of another small hatchery for the breeding and propagation of brook trout (*Salvelinus fontinalis*), which will be distributed on no

smaller scale to the large number of rivers and creeks that have waters of the proper conditions required by the species.

Notwithstanding that the principal object of our Department is, as stated above, the improvement of the diet of the working classes, the propagation of these species will also contribute much to develop a powerful attraction for the tourist, that is, trout fishing with pole and fly.

In regard to other species, we have begun distribution in suitable waters of black bass, bringing this fish from Lake Patzcuaro, Michoacan, where it has increased profusely, and I hope that in the course of one year, the results will be notable in those places where they have been deposited for reproduction.

In having made this brief exposition of the state of our species of fish in interior waters, as well as the propagation and distribution of the fish, I avail myself of this important opportunity provided by the present Convention of the International Association of Commissioners of Game, Fish and Conservation of the United States, to ask all of you, in general, and especially Mr. Frank T. Bell, Commissioner of Fisheries of the United States, and the innumerable persons that handle the fish culture service of our neighboring Republic of North America, for their help in suggestions, counsel, literature, and in general in any way that will aid us to succeed in the task we have imposed upon ourselves for the improvement of fish species in the interior waters of the Republic of Mexico.

Discussion

Dr. A. G. Huntsman: The paper Mr. Berriozábal has just read is interesting. From it we gather that Mr. Berriozábal has the idea that here in Mexico they are still in a very embryonic stage, and that they must look to the United States to learn something; but I must tell you that even in the United States they have not progressed as much as they would like to, and that they have to fight difficulties similar to those confronting you; in fact, I was surprised to hear that success has been obtained with brook trout, because in the United States it is a fish which does not flourish in warm waters, but rather is a cold-water form. It is indeed remarkable that success has been obtained with this fish in a tropical country.

NATURAL REARING ENCLOSURES FOR SMALLMOUTH BLACK BASS

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Abstract

A new procedure for both the introduction and rearing of smallmouth black bass has been tried in lakes of the Prince Albert National Park. The adult bass were transferred before the spawning season and confined in enclosures, screened off, in protected parts of the lake. This procedure allows protection of the parent stock, prevents undesirable scattering, and makes possible accurate observation of survival, spawning activities, etc. Eighty-five adults in enclosures produced 85,000 fry while intensive search revealed no nests from 215 bass released in the open lake.

Rearing was accomplished in "natural" enclosures, that is, protected areas suitable for spawning and cut off by fences of 1-inch mesh galvanized wire. Within these enclosures the bass were handled according to the usual practice in "artificial" rearing ponds.

The chief advantages of the methods used, lie in the degree of control over the introduction of the adults, the economy of rearing, and the ease of distribution of the fry. It is suggested that similar enclosures might be used in breeding and rearing stations either temporary or permanent for bass and related species.

Introduction

Pond culture methods as applied to the rearing of black bass in America have advanced gradually during the past forty years. Among those who have contributed greatly to this development might be mentioned the late Dwight Lydell who did outstanding work in Michigan and T. H. Langlois of Ohio. In recent years variations from the usual procedure have included such experiments as feeding in troughs (Kingsbury and Royce, 1935) and the construction of floating nests and hatcheries (Regan, 1934). The use as rearing ponds of enclosures screened off in favorable portions of larger bodies of water would appear to be a logical application of the pond culture technique which, to the author's knowledge, had not been tried previously.

Opportunity to test this method came in 1936 when it was decided to attempt the introduction of smallmouth black bass into Waskesiu Lake, Prince Albert National Park, Saskatchewan. The author had recommended this introduction after a survey of the game fish possibilities of the area in 1928.

During the past thirty-five years numerous attempts have been made to introduce smallmouth bass into Saskatchewan lakes but none of them proved successful. It was therefore most desirable that the present introduction be made by a controlled method which, even if it failed, would provide much needed information for guidance in fish culture. The present paper is therefore an account of

an experiment in controlled introduction as well as the rearing of smallmouth bass in "natural" enclosures.

Transfer of the Parent Stock

Three hundred adult bass that averaged about 2 pounds in weight were caught by trap-net fishermen at Spanish, Ontario, in the North Channel of Lake Huron. These were transferred 1,700 miles to Prince Albert, Saskatchewan, in an express car equipped with thirty galvanized tanks each of about 20 cubic feet capacity. Aeration was accomplished by dipping water with buckets, and the temperature was maintained within 2° of the original temperature of 48° F., by the use of a small quantity of ice. The water was not changed during the trip and the bottoms of the tanks were cleaned with a siphon twice daily. From Prince Albert the tanks were transported by truck to Waskesiu Lake, 70 miles, and to their final destination by boat. Eighty-five bass were divided among three rearing enclosures and the remaining 215 were released in favorable parts of the lake marked A, B, C, D, E, and F on the accompanying map (Figure 1).

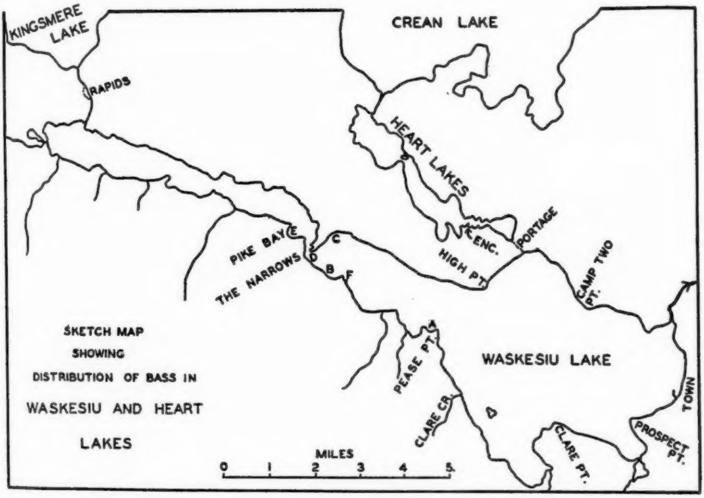

Fig. 1.—Sketch of map of Waskesiu Lake and Heart Lakes.

The trip occupied three full days and all of the 300 bass arrived in vigorous condition. With loading and transfer it was necessary to handle these fish five times but it was done with great care. Move-

ment of the train aided considerably in oxygenating the water in the tanks. The success of the transfer was probably due to the moderate number (ten) of fish carried in each tank, careful handling, and favorable temperatures. An officer of the Dominion Department of Fisheries and the author were in continuous attendance during the trip.

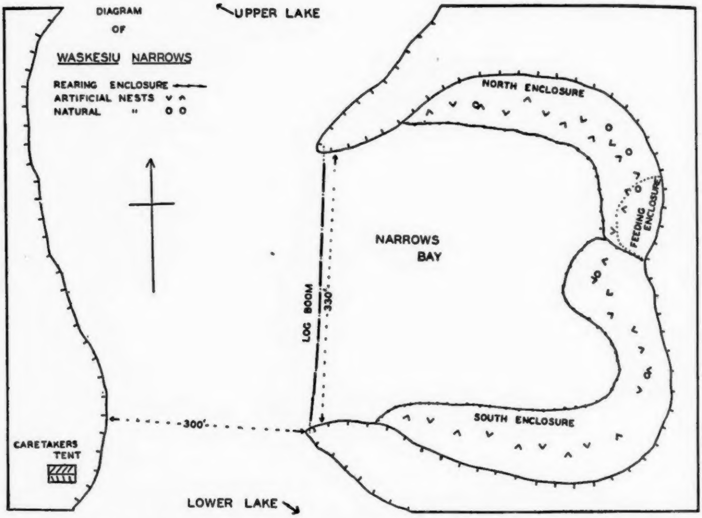

Fig. 2.—Diagram of Waskesiu Narrows showing details of the enclosures in Narrows Bay.

The "Natural" Enclosures

Two of the enclosures used were in a well protected bay with suitable depth and bottom and a third in the nearby Heart Lakes (Figures 1 and 2). In the north Narrows enclosure thirty-one adults (sixteen females and fifteen males) were placed, in the south Narrows thirty-three, and in Heart Lakes twenty-one. These enclosures were about 270 feet long, 45 feet wide and 5 feet deep at the outer margin (Figure 2). The fence was made of 1-inch mesh galvanized wire netting supported at 4- to 6-foot intervals by poles and heavy stakes. The artificial nests were of the usual type (Figure 3) made of rough lumber, and measured 2 feet square, 18 inches high on two sides, and 6 inches on the remaining sides. They were held down by a 3 by 1 foot board across the top and a 50-pound stone, the board also serving to shade the interior. Two bucketfuls of fine

Fig. 3.—Explanatory Legend

1. Protected bay chosen as site for rearing enclosure.
2. Transferring fry from screen-enclosed nest to tub for distribution. The flat "scap" net is of bobinette 8 meshes to the inch.
3. Construction of the nests used.
4. Fry 10 days after hatching.
5. Male bass guarding the nest.

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gravel were placed in the bottom of each nest. The distance between adjacent nests was not less than 20 feet, and the direction of their open sides was alternated. Nest screens were open cylinders of galvanized mosquito netting 30 inches in diameter and 36 inches high.

Spawning

Spawning was first observed on June 21 although some adults had been frequenting the nests since June 17. No fighting among the adult bass was observed. The water temperature in the bay prior to spawning had risen fairly rapidly from 55° to 60° F. (Figure 4). In following spawning temperatures, observations were made at nest level, about 18 inches deep, as well as at the surface where the fluctuations were more pronounced. Readings were made three and five times daily to check the diurnal fluctuation. At nest level this rarely amounted to more than 3°. It should be noted also that temperatures in these enclosed protected bays were at the time 7° to 8° F. higher than the surface temperature of the open lake.

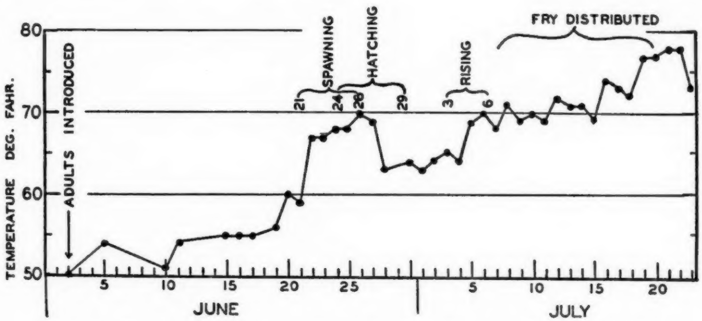

Fig. 4.—Water temperatures at nest level in Narrows Bay, Waskesiu.

It is generally agreed that smallmouth bass require a rising temperature in the neighborhood of 60° F. to stimulate spawning (Langlois, 1933). It is of interest in this connection to note that the bass in Georgian Bay, Ontario, near the place from which the Waskesiu stock was obtained, were also spawning freely on June 20 and 21, 1936 (observed by Mr. K. H. Doan of the Ontario Fisheries' Research Laboratory).

Spawning lasted about six days, being completed in both Waskesiu and Heart Lakes by June 26. A total of twenty-three occupied nests were found in the enclosures which means that approximately 60 per cent of the bass spawned, a very creditable showing in view of the handling which the adults had received three weeks previous.

Of the nesting pairs two-thirds made use of the artificial nests and most of the remaining one-third constructed nests that were situated just outside the artificial ones thereby obtaining some degree of protection from them. In some nests the gravel, chosen in our absence, was too coarse and this is believed to be the reason for the failure of fish to use these nests. In the Heart Lakes enclosure the bottom was soft, and the pairs of bass which did not use the nests cleared off from 6 to 10 inches of ooze before spawning successfully on a mass of roots and debris. Most of the nests were large, in keeping with the large average size of the parent stock.

Extensive efforts were made to locate nests of the 213 adults which had been released in groups of 30 or more in five localities. A total of more than three days was spent in this search, but no natural nests were found. It is difficult to believe that there were no nests in the area covered although the examination was made in favorable weather and all the areas considered to be of suitable depth and bottom type were examined in detail. The only suggestion offered is that either the free bass scattered so widely that few of them nested or that they chose nesting sites unlike those in the enclosure. Bass have been known to spawn in sandy, exposed regions far out from shore (e.g. in Lake St. Clair) but it seems improbable that they would choose such sites if protected bays were readily available.

Hatching and Rising

The first fry hatched on June 24, four days after spawning, and they rose from the nests from July 3 to 6, approximately eleven days after hatching. Temperatures during the period varied from 65° to 70° F., and the growth of the fish was rapid. Those in the Heart Lakes enclosure rose more quickly, probably as a result of the higher temperature which prevailed in that enclosure. After the fry in any nest had begun to rise the wooden nest frame was removed and a cylindrical screen of galvanized mosquito netting was placed around the nest. Care was taken not to disturb the nest prematurely and thus a moderate number of fry were allowed to escape. Some of these were later collected with a fine meshed seine and distributed in the upper lake. The remainder were allowed to scatter freely in the region of the Narrows.

Great losses have been reported by various workers both in pond culture and in natural reproduction as a result of a sudden rise or fall in temperature during the nesting period. The danger of such an occurrence is minimized in the case of "natural enclosures" since the volume of the lake acts as a damper on sudden fluctuations. There is little likelihood of water temperature in Waskesiu Lake rising too high for bass development. The possible effect of continued low temperature was tested by taking fertilized eggs and keeping them in quart jars in a deep root cellar where the tempera-

ture remained between 58° and 59° F. The number of eggs per jar was about fifteen and the water level was kept low in order to allow the absorption of sufficient oxygen. The eggs were placed in the jars on June 25, and hatched in four days. The yolk sac was not quite absorbed when the experiment was stopped on July 16. These fry had taken more than three weeks to develop as far as those in the normal temperature of the lake had advanced in two. Factors other than temperature may have affected the retardation of growth but the important point is that none of the fry died. In other words, unduly cold weather after spawning might be expected to retard development but would probably not kill the embryos.

Distribution of Fry

The total number of fry produced in the three enclosures is calculated as 85,000 of which 66,000 were in Waskesiu Lake and 19,000 in the Heart Lakes. This number from twenty-three nests averages 4,000 per nest. A few nests produced more than twice this number. A total of 60,000 fry were distributed by hand and the remainder were allowed to escape in the vicinity of the enclosures. The method of rearing favoured easy distribution which was done gradually and with great care. The 60,000 fry were spread along about 15 miles of suitable shoreline, most of which was west of the Narrows and especially along the south shore. A rowboat was used for transportation and the fry were released in groups of fifteen to twenty every 50 feet or so along the shore. A total of 45,000 were distributed during the period July 6 to 19. The remainder were held and fed in a special enclosure to be distributed gradually in groups of one or two thousand. Their numbers were thus reduced in accordance with the feeding capacity of the enclosure.

In this connection it might be mentioned that even those fry that were distributed in the early period averaged one-half inch in length and were very active. Under natural conditions, however, they would have been guarded by the male parent for another two to four weeks. The question arises as to whether the loss of this parental care was balanced by the wide and careful distribution. Experiments might be carried out to test this factor in another season.

Growth of the Fry

The growth of the fry was rapid for a lake in this latitude, some individuals reaching a length of 3 inches at the end of August, two months' growth. Daily samples of from six to twelve fry were taken. Their average lengths are plotted in Figure 5. For comparison a second curve is included which indicates the rate of growth of smallmouth bass fry in Lake Nipissing as determined by Tester (1930). The form of the curves is very similar, but the fry from Waskesiu were about 15 per cent longer than those from Nipissing

at the end of the period compared. Measurements were made of total length, that is, from tip of snout to fork of tail. At the last sampling, September 6, the average length was 54 millimeters (2.2 inches) but the individuals in the sample varied rather widely, from 40 to 78 millimeters.

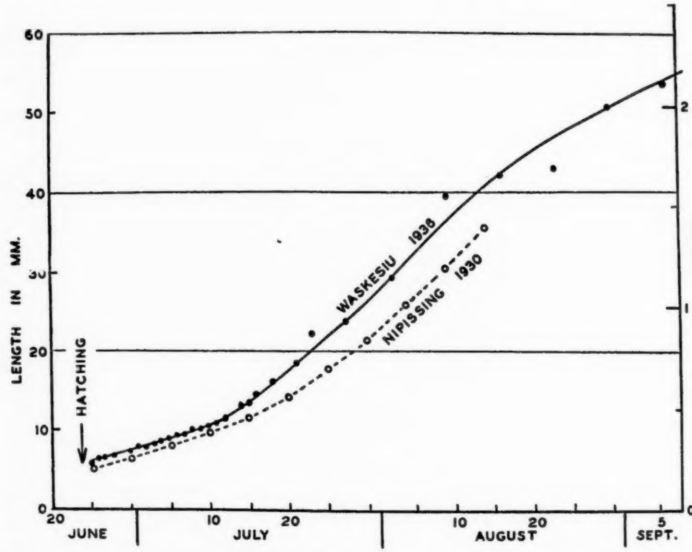

Fig. 5.—Growth of smallmouth black bass fry in Waskesiu, 1936, and in Lake Nipissing, 1930.

A preliminary experiment was made to test the feasibility of feeding some of the bass fry on plankton from the lake. A group of 15,000 fry were placed in a feeding enclosure with an area of approximately 2,000 square feet screened off by galvanized mosquito netting. The enclosure was located within the north Narrows rearing enclosure (Figure 2) in a place very rich in natural food and very well protected. Plankton was collected by towing a large net of No. 10 silk bolting cloth and emptying the catch into a bucket of water at frequent intervals. When the fry in the feeding enclosure appeared, by comparison with those freed, to be lagging in growth part of their number was distributed. At the end of two months the fry in the enclosure were from 15 to 20 per cent shorter than those outside but much more uniform in size. No definite conclusions can be drawn as to the feasibility of feeding fry on plank-

ton collected from the lake but it would appear to be well worth making a further study and a comparison of the cost of feeding in this way and by the usual procedure of rearing *Daphnia* in artificial ponds.

The fry in the enclosure were observed closely to see whether any cannibalism occurred. Such activity might have been expected when the supply of natural food was diminished by crowding but no evidence was found of its occurrence. Possibly the uniformity of growth among the enclosed individuals made it difficult or impossible for one to eat the others. One of the fry taken outside the enclosure on July 21 was found swallowing another half its own length.

Discussion of the "Enclosure" Method

As a method of introducing smallmouth bass into new waters the enclosure method provides a maximum of control. The activities of the bass may be observed and the suitability of the body of water thus definitely determined. The important question of whether they will spawn can be answered in the first season. Such information is a guide for further stocking procedure and may prevent needless expenditure of effort and funds.

The production of 85,000 fry from eighty-five parent bass, only 60 per cent of which spawned, compares favorably with the apparent lack of production, as determined by the absence of nests, in the areas where 215 adults were released. Presumably the latter became widely scattered over the 27 square miles of lake area. There is, however, no proof that the liberated bass did not spawn in the lake. It may be concluded only that the circumstantial evidence favors strongly the enclosure method. We are hoping for an opportunity to test the two methods simultaneously in similar lakes.

If fry are to be planted in any water it would seem to be an advantage to rear such fry on location, where natural conditions of temperature, food, and other factors prevailed and where distribution could be accomplished with ease.

The same enclosure methods if applied to permanent rearing stations would seem to have the same advantages as those found in the lakes. The enclosure provides a near approach to conditions on the natural spawning grounds. Difficulties arising from fluctuation of water temperatures would be minimized and proper water supply assured. The supply of smaller food organisms and minnows is rich at the outset since they are not kept out by the fence. It might be considered that improvement is made on natural conditions in the provision of adequate nesting sites and protection of fry from some of the more common predators.

An equally important advantage is that of the economy involved. The enclosures described above were built of simple and easily ob-

tained materials. Even the construction and use of more permanent enclosures would compare very favorably with the cost of the usual type of artificial rearing pond.

In conclusion we may report that enclosures screened off in protected bays were effective in rearing smallmouth bass in Waskesiu Lake, Saskatchewan. It is suggested that similar methods might be applied to permanent breeding and rearing stations for bass and related species.

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EXPLORING NEW FIELDS IN FISHERIES MANAGEMENT

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Since I am in charge of fishing operations in a state which is now operating a physical plant with inventory value of some $1,250,000 including fifteen fish hatcheries and some seventeen fish rearing stations from which the 1936 production was in the neighborhood of 124,000,000 fish planted in the Great Lakes and 107,000,000 fish planted in the inland waters for the purpose of maintaining or enhancing the productivity thereof, and operating under a budget of $315,000 for the current fiscal year, of which the sum of $35,000 has been budgeted to continue such technical investigation by its Institute for Fisheries Research maintained in cooperation with the State University as appear most urgent and practical, I desire to point out some of the things about which I feel the need for more information.

Inventory of waters. Of waters there are three main sorts: Great Lakes, inland lakes, and streams. Each, of course, will subdivide into various classifications. The sort of classifications we need must evidently relate to the *capacity of given water units to support fish and fishing.*

As with lands, waters will, of course, divide into those which are good, fair, or poor in their capacity to support generous and dependable populations of desired species and combinations of species. As measured in the yearly catch of commercial fish per square mile of water surface, Lake Erie rates high, Lake Michigan medium, and Lake Superior relatively low. In a like manner we could classify our inland lakes and streams for each of the various important fish-species combinations, from carp and suckers to trout and bass. In a very rough way our fishermen have already done this for us. We now know the general character of most of our 5,000 inland lakes and over 15,000 miles of rivers and creeks, and whether they are or are not productive, and for what types of fish.

But we do not know why, though obviously we need to if we are to do a proper job of servicing all those waters. Now, we do not plant trout in bass water, but we are still planting lots of trout in waters concerning whose capacity to support large trout populations we know very little.

In connection with the handling of farm lands, it is common knowledge that the standard farming practices may reasonably be expected each year to produce given quantities and qualities of farm crops per acre. It is now pretty well known what changes will be needed to improve the capacity of those lands to produce the given crops—as through drainage and the use of lime and fertilizers. It is

known that until the natural deficiencies of the land are supplied artificially, the crop yields will not be increased merely by sowing more seed per acre—may indeed be reduced thereby. Just so, I suspect, if a given unit of water is lacking in any phase of productive capacity, its yields of fish cannot be improved merely by increasing the number of the young fish which are planted in it.

We have some lakes where there is such an over-population of small perch that they have become stunted so that few of them ever reach legal size. We have sampled a stretch of one of our good trout streams where undersize rainbows are running 20,000 per mile of stream. Every fisherman knows of lake areas and of stretches on streams which for one reason or another are not worth fishing.

I want to know, for my State, just where these good, fair, and poor water units are, and I want to know why they rate the way they do in productive capacity. Until I have that sort of water inventory, I shall have to doubt whether we are in shape to do a really good job in the handling of our fish-crop operations.

That sort of inventory will evidently involve two main considerations: The natural capacity of the water unit, the available fish food supplies, and the determination of what fish populations are actually present, with the tallies broken down into species and into the percentage of age groups of each. If we should know, for instance, that in a given lake there are already 1,000 young bluegills per acre, we should not be much interested in restocking such water with a few cans of hatchery-reared fish. On the contrary, in a far northern lake much fished by summer resorters, we found good bluegill fishing but no natural bluegill reproduction, presumably because the water never warmed up enough to start the adults to spawning. That might be a very proper lake in which to plant whole truckloads of our pond-reared fingerlings.

Right there comes in another item to be covered by our inventories. To get a rating on given waters as to productive capacity is not apt to be enough; for each water unit we must also know whether it is or is not in shape to keep itself well stocked by way of natural reproduction, provided that enough adult fish are present. Productive capacity does not, by itself, say anything as to the equivalent reproductive capacity. An inland lake might be splendidly productive of northern pike and black bass resulting from hatchery plantings, but if that lake lacked suitable marshy borders for the pike and lacked gravel shallows for the spawning bass so that neither species could maintain itself, then continuous restocking operations would be necessary or the fishing would soon grow poor again. Artificial restocking with hatchery reared fish must always be very expensive as compared with good natural reproduction.

I should want our inventories to recognize whether spawning

facilities were adequate; whether there are proportionate and properly located nursery areas with depth, temperature, and cover suitable for the fry as they leave their beds.

For a 10-mile stretch of first-class brook trout water, for instance, how much should be in spawning gravel and how should this be spaced? How many breeding pairs of fish will it accommodate per 10 square rods of such gravel? How many fry per redd may reasonably be expected to hatch out under normal conditions? Of those which hatch, how many per thousand should reach "keeper" lengths, allowing for normal losses enroute? Of those which reach "keeper" size, what percentage may be spared for the fishermen's creels and still leave enough spawners to stock naturally that 10-mile stretch with all the age groups needed to insure good fishing? I do not know the answers to such questions for brook or for any other kind of trout, or any other species of fish. But should I not know these answers if I am going to help do a proper job of managing the public waters of my State? Our Fisheries Institute is working three field crews this summer on lake inventories of the sort I have been sketching, and our hatchery superintendents and our conservation officers will be helping with this waters-inventory program.

Improvement of waters offers another problem about which I should know more.

On farm lands a lot of people have been experimenting for many years to find out what sizes of tile should be used and how far apart they should be laid to give good drainage; how to build fences which cost little, need little repair, and still turn stock; and where and when lime is needed, how to find out how much is needed per acre; or what combinations of fertilizers should be used in order to give the best results in terms of increased crops and profits on the investment. It is often possible, of course, to increase farm crops by using more fertilizer but at costs which are greater than the increase in the value of the final returns.

If we installed enough refrigerating units, we might change sucker into trout water. But such operations would cost more than they are worth. In all situations there will be a point where the improvement investments run into diminishing returns and do not pay. That, no doubt, will be as true for water farming as it is for upland farming operations.

That is just what we are doing—water farming. When we want to get generous yields of certain species of fish in good variety and in generous quantity, dependably, year after year from the same units of water, then we are trying to handle fish as crops, are we not?

If so, then we must begin to manage our operations and affairs in the way all other crops are managed, and whatever we spend to make the final fish harvests more generous and more dependable must be well worth what it costs since it will presently be up to

the people who spend the money to know what it is really costing to get given results.

When we published our Stream Improvement Bulletin in 1932, we had done enough experimenting to be sure that many improvements therein described would prove practicable and worthwhile and, if properly located and installed, might often change stretches of poor trout water into good, and naturally good water into better. Then suddenly we had the help of the CCC camps, and subsequently, in Michigan, we have done improvement work on some 4,000 miles of trout streams. We hear that many other states and various federal agencies are also experimenting with the new technique.

It is entirely evident that costs of installation and of maintenance of stream improvement devices will run into very large figures if we attempt to put in everything we think beneficial to the fish and the fishermen. Very shortly perhaps we shall not be able to find funds enough to continue this work on the present scale and maintenance alone may become a major problem. In any event from now on it will evidently be up to us to see to it that whatever we do in the way of stream improvements is in fact worth all it costs.

Such costs we shall quite readily be able to figure dependably and before long, in terms of man-days per mile of stream. But how are we going to measure the returns on this investment to be reasonably sure what is or is not worthwhile?

If we knew what number or weight of "keeper" fish per mile of stream or water-acre were being lawfully taken from given water units prior to their improvement and then had similar figures to show the yield of the same waters after improvement, we should be able to measure results as does the farmer with his tile or applications of lime. But how are we going to get such yield figures?

Shall we have to depend upon the voluntary reports of fishermen by asking them to fill out and drop tally cards in boxes set at measured intervals along the improved and unimproved stretches of certain test streams? Or shall we have to employ a special patrol to make personal contacts with all fishing parties? Or again, should we estimate the populations of certain test-streams by installing screens with built-in traps which will be tallied every day, and thus arrive at comparisons of sections of streams which are being heavily fished and others in which all fishing is prohibited? Or, are there still other ways through which we might be able to measure fish populations, and determine the harvest by the fishermen before and after improvement? If I am going to help see to it that our licensed fishermen get good returns on the money they let the Department spend for them, I need to know the answers to such questions—and for lakes as well as streams, of course.

When I left Lansing on this trip, the State printer was beginning to set type for a new publication on lake improvement. This pub-

lication promises to take the form of a book, rather than a bulletin, and I am told by our Institute staff that it will be the first such book in any language. They also inform me that lake-fish combinations are very much more complicated than those for stream-fish, and in many ways less easy to check on or control. Nevertheless it now seems certain that such controls and improvements may often be entirely practicable and highly worthwhile.

Again, of course, these controls and improvements must involve increasingly competent inventories, by types of lakes yet to be classified and named. Then, there must be an inventory of the fish population actually present; estimates of the current carrying capacity of each water unit; and identification of the factors which are seriously limiting fish production therein. Perhaps a relatively slight change of water level, by means of a small dam in the outlet, will flood marshy borders so as to increase the available fish-food supplies and spawning areas. Constructing brush or other shelters on the naked shoals where there is too much barren water may correct this condition. Perhaps adequate and properly located spawning facilities are lacking; perhaps forage fish are scarce and might be introduced to advantage; possibly parasites, diseases, predators, or poaching are serious and need to be controlled. Or it may be that really competent inventories will show that it will be best to leave well enough alone. Some waters, like some lands, will quite certainly prove to be so ill-conditioned and so naturally poor that intensive improvements will not be worthwhile.

In any case, assuredly lake improvement technique is coming fast and is opening up so many large questions for which I have no answers that the prospect leaves me feeling small, and glad that our "answer-getting" machinery is turning over faster and faster in Michigan and elsewhere.

Is it too rude to say that in the guise of service to the fishermen some public fish funds have been or are being spent to very poor advantage, or even so as to create persistent liabilities much greater than the beneficial results? The first Fish Commission in my State was created in 1873, and artificial propagation work started soon afterward. In that number of years there has been time to make a lot of mistakes of course. A number of hatcheries and rearing ponds, for instance, proved when tested to have been badly located or otherwise unfit—in that there was not enough water, or the water was too warm or too cold. Some of these ill-advised projects of our early days were due to toxic political pressures which forced those in charge to choose among various evils.

Such errors were not confined to fish affairs, of course, for the early fire towers and game refuges seem to have had a similar history in my State—but not in your States, I trust. I hope that the historians of our conservation affairs will be generous and will be able to find some benefits even in the early mistakes.

I wonder what the historians will be saying twenty years from now if by then some such disease as furunculosis, inadvertently propagated in the state or federal hatcheries and distributed wholesale, has become endemic among the wild fish as we hear has actually happened in a certain northwestern state. And what will they be saying if, in the name of lake improvement, the record then shows that some exotic species were brought in by the official agencies and turned loose to become a nuisance or a pest? And what will they be saying about presumably responsible officials who, year after year, kept distributing hand-reared fish to waters already stocked to their full capacity with wild-reared fish which cost the sportsman nothing at all? What will be their attitude toward officials who, in order to keep the "sports" quiet, year after year kept sending out good fish to be planted in waters where they had no chance to survive? I can feel sure as to the answers to those questions.

So much, then, for considerations of inventory and improvement, and the many things I need to know about them. Both, in the main, must deal in basically technical affairs—of limnology, hydrobiology, food chains, limiting factors and the like. Such technical studies, no doubt, will long continue to expand and refine—as has happened in the older branches of our crop-wise procedures, such as agriculture and forestry. But there will assuredly be yet another phase of water-crop culture which I am calling management.

Management.—This will involve whatever else we find beyond inventory and improvement that we must do in order to get the technical studies "into gear" with actual practice. Always in such combinations, the technical phases seem to require discounting and heat-treating before they can be widely used—before they are generally understood or accepted by the interested public.

In theory, perhaps, the correct management of public waters is simple enough. A given lake or stream will have its current carrying capacity and ability to feed and otherwise take care of a certain stock of fish. The essential task will be to see to it that the unit is kept as fully stocked as is safe, but not overstocked. Fish-feed should not be allowed to waste but a little such waste will be better than to have the stock growing thin for lack of adequate and suitable food supplies. At regular intervals we want to be able to sell off mature stock to our fishermen—as many adult fish as we estimate we can spare without reducing the stock to the point that good feed is again going to waste. Our arrangements for these operations will constitute the management of our waters and their fish-crops.

To date our management operations have involved the use of three principal tools. The first is season limits, adjusted to permit or encourage a generous natural reproduction of the wild fish, plus creel limits through which we hoped to prevent undue depletion of the stocks, plus more or less enforcement of such restrictive legislation. The second tool is artificial propagation and restocking operations

through which we hope to make sure that any deficits of wild reared young stock will be made up without loss of time, or through which we hope to introduce exotic species which are better than the natives. A third tool is a certain measure of predator control and the removal of noxious species. Until recently these were all the tools available. When we had used them we had done all it seemed there was to be done. If that were so, then why bother to try to find out just what was being accomplished?

But now, evidently we have a new tool coming into use, that is, the modern environmental control such as lake and stream improvement. But to use this tool skillfully requires that we now begin to concern ourselves with decently precise measurements of what we are actually getting for our money. Lacking such information we cannot manage well, and blind trial and error grows less and less satisfactory. We are dealing with water pastures, as it were, and it is up to us to know just what condition they are in and how much of what stock each unit can support and the rate the mature fat-stock may properly be sent to market. For each type and quality of water-unit there will be a quite definite rate per acre each year at which fish can be produced and matured. Good management will require that this rate be determined and that it then be maintained as nearly as practicable at its maximum, using all the tools in the kit.

Anything properly to be called management, in the modern sense, must evidently be based primarily on a knowledge of the relative values of natural and artificial reproduction. At one extreme we may decide to disregard natural reproduction and a balanced series of age groups. Then, if expense is no consideration, we may pond-rear and release "keepers" of almost any size, so as to let them be taken by the fishermen soon after they are planted, as has long been done in some private waters of Europe and as is being done by a few wealthy clubs in America. Perhaps we shall decide to modify this system by requiring the use of barbless hooks so that the uninjured fish when caught are returned to the water soon to be retaken by some other fisherman.

There is no limit to the amount of this "we might do if cost is no consideration." While rearing-pond and hatchery technique will doubtless continue to improve, already we have standard market quotations on live-weight adult trout produced in complete captivity, and so can be quite certain as to the probable costs of this manner of management even though we may not have tried it for ourselves. The prospects are that such fishing will be expensive, probably much too expensive to be maintained in public waters on any considerable scale on present license fees.

At the other extreme, after the desired species have been introduced and have become established in suitable waters we may decide to discontinue further artificial restocking operations in such waters, and to concentrate in making the waters self-maintaining, by im-

provements to insure abundant spawning facilities, adequate shelter, and food for several age groups and so on. Under such a system of management the fisherman would, presumably, be getting very much more for his money than with management of the other sort, but when the safe harvest of adult fish in any water unit had been taken, somebody would have to say to the fishermen: "This water is fished up for this season . . . you will have to quit now so as to leave plenty of spawners to reproduce." Who would make these necessary determinations and announcements? And who would then see to it that on such water the fishing actually *does* stop for the balance of the season?

This basic option as to fish management methods seems to be developing a very close parallel with that which has long concerned our foresters. They also must choose between systems of natural or of artificial regeneration for their growing stocks and manage accordingly. The foresters know that they can start with bare ground, collect tree seed, start it in nurseries, plant out the young trees perhaps 1,000 per acre, thin them when they become crowded, take out the weed trees and cripples, and finally have perhaps 100 good even-aged log trees per acre which may then be cut and sent to market, leaving the land again bare and to be again replanted by hand. This, the foresters know, is the best way to proceed if maximum quality and rate of growth, per acre and per year, are the main consideration; but they also know that to manage forests in such a manner may easily cost more than the timber is worth in the markets.

As against this clean-cut-and-plant system, the foresters will usually prefer to use the "selection system." So managed, the forests will be made up of carefully graduated age groups with some old trees reaching maturity at frequent intervals and with natural seeding from the remaining forest insuring prompt regeneration in the holes left by the removal of the mature and gone-to-market trees. Under this system the quality and yields per acre and year are apt to be less than under the other system, but the production costs are due to be much less as are also the risks. But to keep the selection system in balance requires much experience and skill.

As a matter of fact neither system is, as a rule, used alone. Even under good forest management, natural reproduction does not always occur when or to the extent desired, in which case the nurseries will be used again and some hand-planting done to keep all the land busy.

A similar balance between natural and artificial propagation will probably prove most satisfactory in the modern systems of fish and other wildlife management.

It may well be, as we begin to obtain dependable measurements on what we are actually getting per dollar spent, we shall presently be shifting the distribution of our efforts and budgets so as to use each of the main tools to the best advantage and according to changing

local conditions. If we had done a good job of trying to measure what our fishermen are actually getting for their money, through restrictive legislation, law enforcement, and predator control, and through the planting of artificially propagated fish, and through the use of the modern tinkerings with fish habitats and their improvement, the percentage of our spendings for each might, probably would, require much readjustment.

In the meanwhile, whatever else may be involved, as administrators and public officials, we know that we must first of all try to keep our customers reasonably well satisfied, and that doing so may often prove more difficult than to measure the current yields of trout or bass in certain type waters. And, as administrators we will also know that while most of our technical men are very earnest and increasingly clever with their crop-wise management of fish, they are apt to fail to realize that it may often be even more difficult and important to manage fishermen and their ideas as to what they want and how best to get it.

THE OHIO FISHERIES MANAGEMENT PROGRAM

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The production of annual crops of fish is a service which most water areas can render mankind, and those water areas which would be of most service to the most people by producing fish should be managed in such manner as to produce the most fish. A program is being instituted for improving fishing in the waters of Ohio, based upon a consideration of the natural productivities and fish carrying capacities of those waters, and the application of methods of managing the aquatic habitat and aquatic stocks in such manner as to get the maximum sustained yield of fish.

The *direct method* of fish management involves the regulation of the populations of fish, basing efforts upon the facts of variations in numbers and attempting to maintain that level of abundance which will induce maximum growth and replacement coincident with the greatest withdrawals from the supply that can be taken year by year without jeopardizing future production. Regulation involves principally limiting the toll taken so as to consider first the survival of the species and second the age or time at which the available surplus may best be taken, that is, when the fish have passed the period of maximum growth, have reproduced, have the highest market or pleasure value, and the greatest food value. The replenishment of depleted stocks by introduction of hatchery or pond produced fish is an essential feature of the direct method of fish management, and the addition of such fish to waters serves also to supplement the food producing capacities of those waters. For instance, in Ohio in 1936, approximately 60,000 pounds of game fish were transferred from rearing ponds to public fishing waters. About 300,000 pounds of fish food were consumed by these fishes during their period in the rearing ponds. It has been estimated that our waters produce about 50 pounds of fish food per acre, and on this basis about 6,000 acres of water would be required to produce the amount of fish food supplied to these fish from other sources before placing them in public fishing waters.

The *indirect method* of fish management involves the regulation of the factors which limit the production of ample annual increments of replacement stock to insure the most effective possible utilization of habitat facilities by the fish population. This method involves application of the principles of farm management, includng soil studies, fertilization, plant crop production, intermediate animal crop production, and lastly fish production. Fishes are supported by very complex food chains which may be varied and different for each

species of fish, and all details of these chains have not yet been discovered. Some studies of fish food production have shown little correlation with actual fish production, and studies of the growth rate and abundance of fishes in such waters have appeared to be the only criterion for judging the fish productivities of those particular waters.

Practical fish management involves surveys to diagnose deficiencies and limitations, experiments to develop methods of overcoming these barriers, and the energetic and widespread use of effective methods. Efforts are most fruitful of results when applied to fish populations which are not yielding satisfactory annual increments and to waters which have greater fish producing capacities than are now being utilized. The constantly changing conditions prevailing in aquatic habitats require continuous study, and comparatively little is known about many important factors such as those influencing the fertility of bottom soils. However, among the habitat limitations, may be listed sterile bottoms, turbid waters, inadequate vegetation, and inadequate stocks of fish food organisms, while the fish populations may be limited by inadequate stocks and unbalanced populations. Surveys cannot be frequent enough or complete enough to provide complete data on all waters. The facts obtained at any time must be interpreted as indications of the trends of events, and since such events are successional or cyclic in nature each survey record must be classified as to its place in the succession or cycle.

The Ohio fisheries management program involves the arbitrary division of the State into eleven fish management areas, each consisting of a single large stream system, or a series of small similar stream systems, or a group of comparable lakes or ponds. A biologist either has been or will soon be stationed in each district, with headquarters at a university or college, where he may have access to laboratory and library facilities and can avail himself of the specialized interests of the biology department faculty. Most districts contain one or more of the State fish farms or hatcheries, and the facilities, equipment, and the services of the personnel of these establishments are available in accordance with the needs of the district.

It is the duty of each of these men, called fish management agents, to become thoroughly familiar with the fish populations and fish producing waters in his territory. All information now available is being assembled for the use of these agents. Topographic maps are available for all parts of Ohio, and each man is provided with a complete set for his territory, and soil studies are supplied wherever possible. Records of fish parasites and data on pollution, with records of fish mortalities as well as corrective measures such as mine-sealing operations, are part of each man's equipment.

Cooperation with county farm agents and Smith-Hughes teachers and Federal agencies such as the Soil Conservation Service, Forestry Service, W.P.A., Army Engineers, etc., will be fostered, so that fish

management will proceed as one aspect of planned stream control and utilization.

Research along fundamental lines will be conducted by cooperative arrangement with the Ohio State University through the Stone Biological Laboratory and with the Agricultural Experiment Station at Wooster. A scale study machine has been stationed at the Stone Laboratory and another one at Columbus. The fish management agents take scales when sampling their fish populations and submit them to one of these headquarters, where the scales will be studied as promptly as possible, and reports will be returned to the agents as to age and rates of growth of the fish measured.

Fertile stream bottoms are essential to high productivity, and fertile farm lands make fertile stream bottoms. When erosion has proceeded to such a point that subsoils are being carried into the streams, the fertile stream bottoms become covered with the nearly sterile subsoils. This condition can be prevented only by turfing the tributary valley slopes and reducing the silt load at its source. The growth of tall grasses, weeds, shrubs, willows, and sycamores close to the stream margin also increases the number of insects which reach the surface of the water and become available as fish food. The flooding of fertile oxbows of meandering streams by the installation of carefully placed small dams creates quiet water zones in which small crustaceans become abundant. Small bass and minnows thrive on this kind of food. These small dams also produce holes which serve as refuges for the stream fishes in times of low water or thick ice. About 150 of these small dams have been built with Federal aid in Ohio streams.

Aquatic plants constitute the fundamental crop of biological material, and the physical, chemical, and biological factors which determine the size of this crop control the productivity of a body of water. Aquatic plants have their growth determined by the nature of the available nutrient materials, the amount of available sunlight, and the temperature range of the environment. The rooted aquatics absorb salts, including nitrates, phosphates, and potassium compounds from the soil, and these salts, plus organic compounds are added to the water when the plant bodies decay. These substances augment the growth of planktonic green algae, while the plant remains contribute materially to the amount of organic detritus on the bottom.

All species of American freshwater fishes are known to depend upon the supply of plankton for subsistence during the early growth stages. The plankton of typical clear-water lakes comes in two pulses, one in spring and one in the fall, and these pulses are approximately equal. The plankton feeding stage in the early life of our fishes occurs in the spring, and a copious spring pulse means an abundant food supply, while the autumnal pulse plays no significant part and

has no direct bearing on the problem. Studies have shown that the spring pulse is greatly reduced in waters of low transparency, and varies directly with the clearness of the water. It is known that the dominant year classes of fish are produced in years when the larval or post-larval stages are not destroyed or lost, and there is an apparent correlation between ample spring pulses of plankton and the production of dominant year classes of certain species of fish.

In the water of fish ponds we have observed the delicate balance between transparency and turbidity, with transparency favoring and being favored by leafy aquatic vegetation and turbidity being held low by this agency. We have also seen the balance upset when the water became turbid and the vegetation was destroyed quickly. The part played by leafy aquatic vegetation in maintaining transparency in the lakes and ponds of Ohio may not readily be estimated. Erosion is known to be proceeding at accelerated rates in tributary streams, and the amount of silt being carried into base level waters is considerably greater than formerly. Certain quiet water areas once supported dense aquatic meadows which are no longer present, and it is reasonable to attribute this change to the increased turbidity.

Lakes which contain abundant leafy aquatic vegetation, such as Indian Lake, Buckeye Lake, and Turkeyfoot, are now yielding fairly satisfactory crops of first choice species, such as largemouth black bass, bluegills and pumpkinseed sunfishes, brown and yellow bullheads. Such waters present the most desirable type of balanced habitat, and the only assistance that can be rendered their naturally high productive capacities is the addition of more fish of the desired species to counteract depletion by overfishing. Disturbed balances may occur which require different kinds of corrections. The aquatic meadows may become so extensive that, when the natural harvest occurs in the latter part of summer and the plant bodies sink to the bottom, the processes of decomposition may cause conditions of dissolved gases which may be dangerous to fish. The thinning out and removal of these plant tissues before they die and decompose may be made a profitable undertaking if the plants can be used as food for domestic stock. At least one species of our native leafy aquatic, *Elodea,* has been used as forage for domestic stock in Holland and Germany, and this and other plant species have been considered food concentrates because of their high protein, high lime, and low fiber content.

For impounded waters which are now turbid, like St. Marys, White Lake, Lake Milton, and Sandusky Bay, attempts to improve fishing must take one of two lines of endeavour, namely that leading to the restoration of transparent waters with the aquatic meadows and the first choice fish species, or that leading to improved conditions for the second choice species now present (crappies, catfish,

carp). If the conditions which brought about high turbidity and eliminated the aquatic meadows still prevail, such as large silt loads in tributary streams or exposure to unimpeded strong wind action, it may be futile to try to restore former conditions. Possibly rhizome spreading slender stemmed bulrushes could be used to pave the way for the later introduction of other species. A number of aquatic plants can be established by planting seeds, while others can better be established by cuttings.

If the conditions which brought about high turbidity and elimination of the aquatic meadows are still operative, it is advisable to try to improve fishing for the second choice species which now dominate the fish population. Crappies appear to run in natural cycles, with the young produced in given years constituting the bulk of the catch for several years. The level of Lake St. Marys was phenomenally low in May, 1931, and the crappies produced there that month formed the bulk of the crappies caught during 1933, 1934, and 1935. The crappies caught there in the spring of 1933 averaged 9 inches in length, in 1934, 10½ inches, and in 1935, 12 inches. A few 14-inch crappies were caught in Lake St. Marys in 1936, but a new group of 9-inch crappies appeared in the catch in 1935, and most of those caught in 1936 were about 10½ inches long. Studies need to be made of the factors which permit the production or survival of many crappies in some seasons and prohibit it in others.

Channel catfish are caught after the spring run of crappies is over in Lake St. Marys, and the provision of old tiles or kegs for the spawning of this species probably would add to the success of its reproduction. Both channel catfish and crappies consume quantities of gizzard shad in Lake St. Marys, and methods of increasing the abundance of shad would further the welfare of the catfish and crappies by increasing their food supply.

The social relationships of catfish, crappies, shad, and carp, all of which are abundant in Lake St. Marys, are unknown in most aspects. Whether the young, yearlings, or adults of one species prey upon the eggs, young, or adults of another may determine the welfare of either species. The habits of a species in seeking particular conditions to spawn may bring it into competition with another species for limited areas where suitable conditions for both prevail, or the result may be the exposure of the young of one to the appetites of another. Response to rough water usually carries crappies to the depths and catfish to the lee-shore, and the food desired by each may be scarce in those regions.

Too little is known about the effects of introducing strange fish into an established social system, both upon the system and upon the fish placed in it. There is doubtless a definite succession

of sociological formations in each type of mixed fish populations comparable to that known to occur among black bass in rearing ponds, and these sociological successions must be determined. The addition of a quantity of new fish individuals to an established order must influence the nature of this succession and may alter it favorably or unfavorably. The sudden thrusting of fishes into an unknown environment places them at a definite social disadvantage, and methods should be devised for reducing the handicap of the stranger if the stocking of fish in public waters is to bear fruitful results. More facts must be obtained, and more research must be directed toward finding the use for the facts already available.

EXPERIMENTAL MANAGEMENT OF A GROUP OF SMALL MICHIGAN LAKES

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Abstract

Eight small pit lakes, located in the Pigeon River State Forest, were considered to be ecologically suited to trout as determined by a physical, chemical, and biological survey of these lakes in 1931 and 1932. Four of the lakes were found to be over-run with yellow perch, the other four originally contained only forage fish. Trout (chiefly brook trout) were stocked in each of the lakes. They grew and survived well in those lakes which did not contain perch but were relatively unsuccessful in the "perch" lakes. One of these lakes was fertilized with phosphate and later yielded both trout and perch of fair size, the other three were poisoned and later restocked with trout and, in one instance, with Montana grayling.

The trout were not easily caught in mid-summer, and, for this reason, the lakes were opened to fishing during the regular trout fishing season starting about May first.

Creel census on some of these lakes for several seasons indicates that the yield varied from 4.3 pounds per acre of trout in one lake to 30 pounds per acre of trout in another lake.

These lakes, once valueless for fishing, are now attracting some of the anglers away from the heavily fished, perhaps over-fished, section of the Pigeon River which flows through the immediate vicinity.

Introduction

The Pigeon River State Forest, a tract of about 113,000 acres of sandy soil in the north central part of the Lower Peninsula of Michigan, has within its boundaries a group of small lakes locally known as "pot-holes." These lakes correspond with the description and figure of a typical pit lake as given by Scott (1921) who states that "this type of lake was probably formed by the isolation of an ice block which became covered with debris and melted later, allowing the material to settle." The lakes are circular in outline with high, steep, sandy banks.

As a result of a proposed program of land utilization for the forest, these pit lakes, nine in number, were inventoried, along with other lakes in the forest, by the Institute for Fisheries Research in 1931 and 1932 and a program for experimental management of the lakes was set up. One of them was too shallow to be of value for desired species of fish, the other eight are discussed below.

In managing these lakes emphasis has been placed on trout. That portion of the Pigeon River which flows through the immediate vicinity of the lakes is heavily fished. In recent years it has given only mediocre results as a trout stream. It was felt that if

TABLE 1. PHYSICAL AND CHEMICAL DATA OBTAINED FOR EIGHT LAKES IN PIGEON RIVER STATE FOREST, 1931 AND 1932

Item	Ford	Devil's Soup Bowl	Hemlock	Lost	West Lost	Section Four	North Twin	South Twin
Area (acres)	11.7	1.3	6.0	4.6	4.0	3.3	5.7	4.3
Per cent shoal[1]	35	35	35	15	15	15	15	15
Inlet	None	None	None	None	None	None	None	None
Outlet	None	None	Intermittent	None	None	None	None	None
Vegetation on shoal	Abundant	Moderate	Abundant	Common	Common	Common	Common	Common
Maximum depth[2]	10.0	6.9	19.2	15.8	14.5	21.9	15.8	12.7
Location of thermocline[2]	5—bottom	3—bottom	4—8	4—8	3—7	4—7	5—9	5—9
pH at surface	8.2	7.8	8.1	7.9	7.9	7.9	7.5	8.1
pH at bottom	8.2	7.6	7.4	7.4	7.0	7.2	7.4	7.8
Dominant bottom type[3]								
Shoal	S, P, M	P, S	P, M	M	P, S	M	S	S
Slope	M	P	M	M	M, P	M	P	P
Deep	P	P	P	M, P	P	M	P	P
Secchi disc (meters)	5.5	5.1	4.2	9.1	5.0	6.8	4.5	7.5
Temperature at surface[4]	75° F.	73° F.	70° F.	74° F.	74° F.	76° F.	76° F.	73° F.
Dissolved O_2 (ppm)[4]								
Surface	9.4	5.8	8.7	8.4	6.7	9.1	8.3	6.4
3 meters	—	5.4	—	—	—	—	—	—
5 meters	9.3	—	—	7.7	—	—	—	7.9
6 meters	—	5.0	—	—	—	—	—	—
7 meters	—	—	—	—	6.0	11.1	—	—
9 meters	—	—	—	—	—	—	11.2	—
10 meters	8.6	—	6.0	11.0	—	—	—	7.0
14 meters	—	—	—	—	0.0	1.7	—	—
15 meters	—	—	—	0.8	—	—	8.9	—
19 meters	—	—	2.2	—	—	—	—	—
21 meters	—	—	—	—	—	0.0	—	—

[1]Rough estimate.

[2]Depths in meters.

[3]S = sand, P = peat, M = marl.

[4]Dates of analysis: Ford 8/1/32, Devil's Soup Bowl 8/2/32, Hemlock 7/28/32, Lost 8/1/31, West Lost 7/29/32, Section Four 8/1/32, North Twin 7/27/32, South Twin 7/27/32.

good trout fishing could be provided in these small lakes the angling pressure on the river would probably be diminished.

Inventory

A physical, chemical and biological survey of these eight pit lakes indicates (Table 1) that they vary in size from 1.3 acres to 11.7 acres and in depth from 22 feet in Devil's Soup Bowl to 72 feet in Section Four Lake; all are alkaline and all are stratified, with relatively warm surface water (70° F. to 76° F. surface temperature on dates shown in Table 1) but with oxygen ample for fish life in the colder water below the thermocline. The water is clear in all the lakes: Secchi disc readings varied from 13½ feet in Hemlock Lake to 30 feet in Lost Lake. Five of the lakes (Lost, West Lost, North and South Twin and Section Four) are almost perfectly circular, are land-locked, have very limited shoal areas and relatively scant vegetation. The other three lakes are similar except that Devil's Soup Bowl, the smallest and shallowest, has more vegetation, Hemlock has an intermittent outlet with a weedy, marshy border adjacent, and Ford Lake, the largest, is more irregular, has more shoal area, and somewhat more vegetation.

A study of the fauna (Table 2) showed that all of the lakes contained fish, but that very few species were represented. Yellow perch only were found in three of them; in another a few suckers were taken in addition to perch. The suckers were large and few in number and may have been introduced by anglers a few years before. The other four lakes contained only forage fish until brook trout were stocked in two of them in 1927. Only one species of fish, the fat-headed minnow, was found in the three

TABLE 2. DISTRIBUTION OF FISHES[1] IN EIGHT LAKES IN THE PIGEON RIVER STATE FOREST AS DETERMINED IN 1931 AND 1932
("A" denotes abundant, "C" common, and "R" rare.)

Lake	Brook trout	Yellow perch	Common sucker	Northern creek chub	Northern red-bellied dace	Northern black-nosed shiner	Northern fat-headed minnow	Iowa darter	Brook stickleback
Ford		A							
Devil's Soup Bowl							C		
Hemlock	(A)[2]			C	A	A	C	C	C
Lost	(A)[2]						A		
West Lost							A		
Section Four		A							
North Twin		A	R						
South Twin		A							

[1]Scientific names, corresponding to the common names, in the order listed, are: *Salvelinus f. fontinalis*, *Perca flavescens*, *Catostomus c. commersonnii*, *Semotilus a. atromaculatus*, *Chrosomus eos*, *Notropis h. heterolepis*, *Pimephales p. promelas*, *Poecilichthys exilis*, and *Eucalia inconstans*.

[2]Stocked in 1927.

land-locked lakes. Six species were taken in the lake with the intermittent outlet.

From the management angle, the lakes constitute two distinct groups: four containing perch and four without perch. The perch were extremely abundant in the four lakes, but were small, in very poor condition, and were obviously stunted in growth. The brook trout which had been stocked in Lost and Hemlock lakes were in good condition, and in Lost Lake were providing excellent fishing in 1931, when their presence was discovered by the anglers. Until the trout were planted none of the eight lakes was of value for fishing.

Management

All eight lakes seemed ecologically suited for trout and, in 1933, all were stocked with brook trout by the Oden Hatchery (Table 3). It was understood, of course, that little or no natural reproduction could be expected, because spring fed gravel shoals and tributary streams were lacking; and that stocking would need to be continued at more or less regular intervals if fishing was to be maintained. Four of the lakes have been stocked annually during the last several years.

TABLE 3. RECORD OF PLANTINGS MADE BY THE ODEN HATCHERY IN EIGHT LAKES IN THE PIGEON RIVER STATE FOREST, 1933 TO 1936[1]

Lake	Year	Species	Number	Age	Approximate length (inches)
Ford	1933	Brook trout	500	8 months	4
	1934	Brook trout	6,000	6 months	2
	1934	Brown trout	600	8 months	4
	1934	Rainbow trout	600	Yearlings	6
	1935	Rainbow trout	300	Adults	9
	1936	Grayling	5,000	10 months	2½-3
Devil's Soup Bowl	1933	Brook trout	5,000	5 months	1¾
	1934	Brook trout	500	6 months	2
Hemlock	1933	Brook trout	5,000	5 months	1¾
	1934	Brook trout	10,000	5 months	1¾
	1935	Brook trout	5,000	5 months	1¾
	1936	Brook trout	3,125	7 months	3
Lost	1933	Brook trout	5,000	5 months	1¾
	1933	Brook trout	500	8 months	4
	1934	Brook trout	6,000	6 months	2
	1935	Brook trout	5,000	5 months	1¾
	1936	Brook trout	3,125	7 months	3
West Lost	1933	Brook trout	5,000	5 months	1¾
	1934	Brook trout	6,000	6 months	2
	1935	Brook trout	5,000	5 months	1¾
	1936	Brook trout	3,125	7 months	3
Section Four	1933	Brook trout	300	8 months	4
	1935	Rainbow trout	150	Adults	9
North Twin	1933	Brook trout	1,300	8 months	4
	1933	Brook trout	5,000	5 months	1¾
South Twin	1933	Brook trout	1,500	8 months	4
	1933	Brook trout	5,000	5 months	1¾
	1935	Rainbow trout	100	Adults	9

[1]Mr. Guy Lincoln, District Supervisor of Fisheries, who provided the above data, indicates that the size given is only approximate and that these sizes refer only to fish from the Oden Hatchery. The several small plants made by private individuals in 1927, and the several plantings of forage fish made by the writer are not included in the table.

The benefits to be derived, in general, from past and current stocking practices for maintenance of our lake fishing are now being questioned to an increasing extent, but in this particular group of lakes stocking is largely responsible for the annual catch of fish.

In recent years the lakes have been designated as "trout" lakes and fishing on them has been permitted during the regular trout fishing season, currently starting on the last Saturday in April. Originally these lakes were closed until June 25. It seemed desirable to keep the lakes closed to fishing until a relatively late date to accommodate better the heavy mid-summer fishing; but experience has indicated that, in lakes, trout are much more readily taken earlier in the year. An increase in the catch no doubt has resulted from this change in the fishing season. Most of the fish are now taken in May and June.

Management of the four lakes, which did not contain perch, has been limited to stocking with brook trout and to a change in the fishing season. In several of these lakes an excellent yield has resulted. It is reported that recently one of them, Devil's Soup Bowl, has been stocked with brown trout. In the writer's limited experience with brown trout, he has found that this species is not readily caught in lakes. The fishing in Devil's Soup Bowl will be carefully noted to determine the advisability of further introductions of this species.

Stocking of trout in the four lakes containing perch was uniformly unsuccessful. Experimental fishing with gill nets indicated that the growth of the trout in these lakes was very slow and that few of the planted trout survived. The lakes yielded few or no fish of desirable size and were valueless for fishing. Two of them, South Twin and Section Four, were poisoned with rotenone to eradicate the perch and were restocked with adult rainbow trout, the former also with forage fish. A creel census on South Twin Lake indicates that over half of the introduced trout were taken by the anglers during the first season.

North Twin Lake was fertilized. Several hundred pounds of phosphate fertilizer were suspended from a raft in the center of the lake in 1934. Limited returns (general creel census) for the fishing in this lake indicate that in 1936 twenty-one brook trout averaging 11½ inches in length and forty-eight perch of an average length of 6½ inches were taken in twenty-two hours of fishing. An intensive creel census now being taken on North Twin Lake indicates that the perch averaged about 7½ inches in length. It has not been proven that the fertilizer was responsible for the successful growth and survival of the trout or for an apparent increase in the size of the perch; however, in the three lakes which were similar, but which were not fertilized, no such results were obtained.

A variety of attempts were made to improve fishing in Ford Lake, the largest of the group. *All were unsuccessful as long as perch were present.* When it was found, in 1934, that the brook trout were not doing well, the lake was heavily netted with gill nets to reduce the population of perch. A total of 1,137 perch (5.6 pounds per acre) was removed. These fish represented one-sixth of the quantity of perch (by weight) which were present in the lake two years later. Several species of forage fish were introduced. The lake was stocked with brook, brown, and rainbow trout in 1935. A few thin and poorly colored trout were caught in 1936 and the lake was still of little value for fishing. The perch had improved in condition but were still growing slowly.

All fish were removed by poisoning with rotenone coupled with heavy dynamiting beginning September 20, 1936. Five thousand Montana grayling fingerlings were stocked on October 31, 1936. An examination of the lake the next spring (May) indicated that the grayling had survived well. The majority of those examined were in good condition and showed reasonable growth. They were not yet of catchable size. Whether or not the lake will eventually provide good grayling fishing still remains to be determined.

Catch

A knowledge of the catch is necessary if the relative success of the various fish management practices is to be determined adequately. Fortunately it was possible to maintain a complete creel census on Lost, West Lost, and Hemlock lakes in 1935 and on these lakes and South Twin Lake in 1936. The creel census was taken by Camp Pigeon River (M. E. C. W.) and Camp Vanderbilt (U. S. Parks Service). At present a creel census is being taken on all of these lakes except Section Four which is "off the beaten path" and is little fished, and Ford Lake which now contains only small grayling and which is closed to all fishing.

According to the census records (Table 4) the catch in Lost Lake in 1935 consisted of 461 brook trout having an average length of 8.9 inches. The fish had a total weight of 139 pounds. The catch on this 4.6 acre lake was therefore exactly 100 trout or 30.2 pounds per acre. In 1936 the catch was only thirty-six brook

TABLE 4. TREND OF THE CATCH AND SIZE OF BROOK TROUT TAKEN IN LOST, WEST LOST, AND HEMLOCK LAKES IN 1935 AND 1936

Lake	Year	Number caught	Pounds per acre	Average size (inches)
Lost	1935	461	30.2	8.9
	1936	166	11.8	9.3
West Lost	1935	199	23.5	10.5
	1936	254	22.5	9.4
Hemlock	1935	215	8.0	8.1
	1936	52	4.3	10.6

trout (12 pounds) per acre. For that year the fish had an average length of 9.3 inches.

Data for the 1931 fishing on Lost Lake, compiled chiefly from the general creel census taken by conservation officers, indicate that by the end of the opening day 162 brook trout averaging 10 inches in length had been caught. Since only 200 trout had been planted (as fingerlings in 1927) fishing was obviously poor for the remainder of the season.

Anglers took fifty fish per acre from West Lost Lake in 1935 and an average of sixty-three and one-half fish per acre the next season. The trout caught in 1935 had an average length of 10½ inches; in 1936 they averaged an inch shorter. In pounds the catch per acre declined slightly the second year, from 23½ pounds in 1935 to 22½ pounds in 1936.

Hemlock Lake yielded good fishing in 1934 according to the writer's frequent observations of this lake during that season. The next year the catch was only 8 pounds per acre and in 1936 only about half that amount. Hemlock Lake is one of the deepest in the group, and temperature and oxygen conditions are favorable for trout. It also appears to be one of the richest in food; the marsh which borders the lake near the outlet seems to be especially productive. The lake has been well stocked with trout. Reasons for the poor yield from Hemlock Lake in recent years have not yet been determined.

The census on South Twin Lake indicates that 62 of the 100 adult rainbows stocked in this lake in the fall of 1935 were caught during the next fishing season.

A study of the effectiveness of the various kinds of bait used failed to show any one bait as outstanding. Minnows and worms were most used. Artificial flies were among the most successful baits.

Anglers were attracted to these small lakes from a wide range of localities. For example, Lost Lake in 1936 was fished by residents from seventeen counties and by non-residents from three states.

Rate of Growth of Brook Trout

No studies were made of the growth of the trout from scale examinations, but in a few instances some information on growth was obtained as a result of creel census returns. In Lost Lake the fish caught in June, 1931 averaged 10 inches in length. They were four and a fraction years old. Six brook trout taken from Hemlock Lake in 1932 had apparently attained an average length of 19½ inches in five and a fraction years. One trout taken in Lost Lake in 1935 had a length of 22 inches, and was probably of the original stocking made in 1927. The 9-inch size group predominated in the 1935 catch in Lost Lake and the 11-inch size group

predominated in West Lost Lake. Both were probably two and a fraction years old since these lakes were first stocked in the summer and fall of 1933 (except for the stocking in Lost Lake in 1927) with fish 5 to 8 months old.

Survival of Trout Plantings

Survival of the stocked fish varied from a fraction of one per cent in one lake to almost a hundred per cent in several small plants. Of the 200 brook trout planted as fingerlings in Lost Lake in 1927, 167 are known to have survived since this number was actually caught. Of the 100 adult rainbow trout planted in South Twin Lake 62 were taken by anglers and 2 were obtained in gill nets set to determine whether the perch had been completely exterminated. Recent examination of the lake, when the trout happened to be feeding at the surface, indicated that most of the remaining thirty-six were still present at the opening of the current fishing season.

After stocking was increased to some hundreds of 5 to 8-month-old trout per acre the number caught represented only a very small percentage of the number planted. Of 16,500 trout planted in Lost Lake from 1933 to 1935 approximately 1,000 were caught in the years 1934 to 1936. Even fewer were taken from West Lost Lake during the same period. This lake had been stocked with a total of 16,000 fish in the three years from 1933 to 1935.

What happens to the other fish (about 95 per cent of those stocked) is not definitely known. The recent report by one of the census-takers that a large brook trout taken from one of these lakes had six smaller trout in its stomach suggests the possible fate of some of them. A considerable number of the trout probably die at the time of stocking or soon thereafter. Many dead fish were noted by the writer in these lakes in 1934 immediately after they had been planted.

In the lakes over-run with perch, survival of trout was negligible. Of 8,000 trout, including some adults, stocked in Ford Lake, 15 brook trout were taken in gill nets in 1934 and 27 were recovered by the poisoning and dynamiting of the lake in 1936. Very few had been removed by angling.

Survival of Forage Fish

Two of the lakes, Ford and South Twin, were stocked with forage fish. To improve food conditions in Ford Lake approximately 15,500 fish were planted in July, 1934. These fish, from a beaver pond in a very small tributary of the Pigeon River, were mostly northern dace (*Chrosomus eos*), although limited numbers of fat-headed minnows (*Pimephales promelas*), sticklebacks (*Eucalia inconstans*) and mud minnows (*Umbra limi*) were included. On the basis of counts along measured sections of the shoreline at the time of the poisoning

in 1936, the number of forage fish was conservatively estimated to be 36,700. None was found at the time of the survey in 1932 nor could any have entered by connecting waters since the lake has neither inlet nor outlet. All species which had been planted survived except sticklebacks, and one or more of them had increased in number even though this lake was over-run with perch.

South Twin Lake was stocked with about 5,000 blunt-nosed minnows (*Hyborhynchus notatus*) and about 50 Menona killifish (*Fundulus diaphanus menona*). A brief examination of the lake in 1936 indicated that blunt-nosed minnows were abundant. It is possible that the Menona killifish also survived. The lake had been previously poisoned and no fish were present at the time of the stocking with forage fish. Their survival and probable increase in number was therefore not surprising.

Perch

The perch which were killed in the three lakes were collected and were later studied in detail. The findings are discussed in two papers by the writer (Eschmeyer, 1937, 1938) and only a few of the details are listed here. Later examinations of the lakes have demonstrated that all perch were probably killed, for gill-net lifts, seine hauls, and creel census records failed to reveal any perch.

In each lake the young fish were dominantly males; the older and larger fish were almost all females. The females grew more rapidly than the males. These findings are in accord with those of Huitfeldt-Kaas (1927) for the European species, *Perca fluviatilis*.

The perch grew very slowly in all three of the lakes and few reached a catchable size. In South Twin Lake most of the fish died of starvation before reaching the legal length of 6 inches.

The rate of growth was not correlated with the condition of the fish. Perch which were in excellent condition nevertheless grew quite slowly.

The total population of fish (chiefly perch) per acre varied from 30 pounds in South Twin Lake to 50 pounds in Ford Lake. The number of perch per acre varied from 452 in Ford Lake to 955 in South Twin Lake. The fish of legal length were chiefly females.

An explanation for the more or less frequently observed phenomenon that perch tend to school according to sex was found in Ford Lake. An examination of the stomachs of a hundred perch of each sex taken at the same time by poisoning indicated that the females had been feeding primarily in shallow water. Minnows constituted their chief food and winged ants were prominent in their diet. The males, smaller in size, were apparently in much deeper water. Their food was primarily midge larvae. It seems therefore that the tendency of each sex to school separately may be due to a difference in food habits resulting from a difference in the rate of growth of the two sexes.

Trend of the Fishing

On those lakes where a creel census has been taken for several seasons the trend of the yield is definitely downward. It is possible that food may have decreased in two of the lakes. Perhaps they were overstocked. However, food is apparently abundant in Hemlock Lake where fishing for several seasons has been poor. If the fishing in these lakes is to be maintained the reasons for the gradual decline in yield must be determined.

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A CREEL CENSUS AT CHAUTAUQUA LAKE, NEW YORK

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Abstract

An important part of the biological survey of the Allegheny watershed in New York State during 1937 consisted of a study of angling conditions in Chautauqua Lake, a highly productive, comparatively shallow body of water of 13,376 acres. This lake is noted for its black bass and muskalonge fishing. The main objective of the study was to lay a foundation for later more intensive investigations leading to a sound management program. Owing to the popularity of the lake among fishermen on opening days and to the fact that July 4th fell on the first week-end, a high concentration of anglers afforded a good opportunity for obtaining a large amount of the necessary data.

During the first five days of the season (July 1 to 5) sixteen members of the Survey's scientific staff were stationed at strategic points around the lake, such as the boat liveries, and obtained data as to the kind, number, length, and weight of the fish caught, the number of hours of fishing, and the type of gear and bait used by each fisherman contacted. Scale samples for age determinations were obtained from 221 smallmouth bass, 206 largemouth bass, and 73 muskalonge.

The analysis of the creel census data for the five-day period showed that a total of 3,732 legal fish were taken in 1,488 fisherman-days, or 6,788 fisherman-hours, an average of 0.55 fish per fisherman-hour. Of the total number of fisherman-days reported 45.9 per cent showed no catch of legal fish. The total catch enumerated consisted of 284 smallmouth bass (7.6 per cent), 212 largemouth bass (5.7 per cent), 80 muskalonge (2.1 per cent), 159 bullheads (4.3 per cent) and 2,997 pan fishes (80.3 per cent), chiefly perch, rock bass, and sunfishes.

Introduction

Fisheries administrators are beginning to recognize that an accurate knowledge of the size of the annual "harvest" is an essential factor in the management of wildlife resources. In regions where the demand for sport fishing exceeds the supply, the fishery manager is being called upon to farm the public waters to their fullest extent. Stated in another way, the manager's aim should be to get the greatest yield annually that is compatible with the maintenance of stocks at a steady level. It would be considered highly unbusinesslike to run a commercial enterprise without keeping a record of the income, expenditure, and stock on hand. Such a policy may work after a fashion as long as the returns are considered to be satisfactory but in many of the fisheries it is becoming increasingly apparent that the returns are getting perceptibly less from year to year. The recognition of this fact dictates a more businesslike approach to the problem of farming the waters. Measuring from year to year the harvest or angler's take of fish will undoubtedly furnish a good deal of the data that are necessary to

convert fisheries administration from a haphazard system based on inadequate knowledge to a businesslike enterprise.

Fisheries biologists are doing some necessary spade-work in this field, as shown by the number of technical papers that have appeared in recent years. Judging from these contributions, the creel-census method of estimating the harvest is apparently a useful agency in the hands of scientific investigators working on small lakes and streams; but the practical application of the method is still in the pioneering stages.

The New York State Biological Survey has been investigating the fact-finding possibilities of the creel-census method in the course of its recent survey studies. An important part of the survey of the Allegheny watershed, in 1937, consisted of an appraisal of the Chautauqua Lake sport fishery. An opportunity was afforded to try out the census technique in the hands of trained biologists working on a large lake, and at the same time to obtain information on the fishing effort, the fishing drain, and the relative abundance of the various species of sport fish. Although the data obtained were limited and of a preliminary nature, it seems desirable to publish them as a step toward a practical creel-census procedure.

The field blank used in the Chautauqua Lake work is similar to the type used in the Michigan creel census (Eschmeyer, 1936).

Chautauqua Lake is the largest and most important lake in the Allegheny watershed. It has an area of about 13,400 acres with a shoreline of approximately 42 miles. It is a natural body of water with an annual, vertical fluctuation of less than 4 feet. The lake is divided into two nearly equal parts by a narrows. The two areas differ considerably in depth; the north end has a numper of "pot-holes" from 60 to 77 feet deep, whereas the south end nowhere reaches a depth of 20 feet. In the northern part of the lake there is an area of about 4,000 acres where the water is over 35 feet deep and, during much of the summer, there is a lack of dissolved oxygen below a depth of about 40 feet. The flora and fauna are abundant. The lake has long been noted for its fish production.

The number of boats available at the boat liveries around the lake was conservatively estimated at 300 $\pm$ 50 boats, and there is probably an equal number of boats, available for fishing, owned by cottagers. This gives a fairly high, potential fishing population of one boat to 20 acres or about 14 boats per mile of shoreline, exclusive of the fishing carried on from the shore itself. The boat population is an important consideration in studying the fishing intensity on lakes, but it has previously received little attention from investigators.

Owing to the fact that the census takers had to be drawn from their regular duties to undertake the work, it was impossible to

carry on the census for more than a few days. In order to obtain as many data as possible in the limited time available, the first five days of the bass and muskalonge season (July 1 to 5 inclusive) were selected, because it was believed that these days would afford a high concentration of anglers at a convenient time. Accordingly, sixteen members of the survey staff[1] were stationed at strategic points around the lake, particularly the main boat liveries, where they contacted the fishermen. It is estimated that the workers "sampled" over half of the fishermen on the lake during this period.

It should be pointed out also that the census provided an unusually good opportunity for obtaining biological data on the game fish. Scale samples, length measurements, and weights were obtained during the census from 73 muskalonge, 221 smallmouth bass and 206 largemouth bass. It would have been almost impossible to have obtained an adequate series of samples of the muskalonge in any other way. As a rule, the anglers are glad to assist in furnishing these data, if a little explanation of the purpose of the material is given at the time. The explanation that the scale samples are used for determining the age of the fish seldom fails to arouse the interest of the fishermen in the scientific work of the Department, and the census therefore has an educational value that could have been achieved in no other way.

Analysis of the Census Reports

Analysis of the Fishing Effort. A total of 1,012 reports was turned in by the 16 persons taking the census records. This represents a return of 12.6 reports per census-taker per day which is evidently a very low number of returns in proportion to the cost of obtaining this information. The cost per return could be cut down to a great extent, however, by sampling only the more popular boat liveries if this method proves to give samples representative of average fishing effort. Costs could be reduced further by utilizing voluntary cooperators, such as local sportsmen and boat livery proprietors. It is essential, however, to provide sufficient skilled supervision to insure training of each field worker in uniform methods of reporting returns.

The reports returned represented a total of 1,488 fisherman-days or 6,788 fisherman-hours. Some of the reports were made on a boat basis; others were made out for each fisherman. Where reports were made per boat and the number of fishermen was not reported, an average of 1.8 persons per boat, which was obtained from the more complete reports, was used to compute the total fisherman-days and the total fisherman-hours.

[1]The following Survey members assisted in collecting and organizing the data for this paper: R. M. Bailey, S. M. Brown, G. E. Burdick, W. R. Duden, Dr. C. W. Greene, Mrs. C. W. Greene, Dr. W. J. Koster, S. J. Makosky, Dr. C. McC. Mottley, Dr. J. F. Mueller, R. W. Odell, Dr. T. T. Odell, Miss M. E. Pasco, Dr. R. C. Tasker, Dr. H. K. Townes, Dr. W. L. Tressler, and E. H. Wheeler.

TABLE 1. AGE, SEX, AND RESIDENCE OF ANGLERS

Sex and age	Total number of reports	Percentage	Number of residents	Number of non-residents	Number of reports, residence not reported
Males over 16	907	89.6	793	108	6
Males under 16	30	2.9	27	3	—
Males, age not reported	8	0.8	—	—	8
Females over 16	29	2.9	27	2	—
Females under 16	11	1.1	8	2	1
Females, age not reported	2	0.2	—	—	2
Sex not reported	25	2.5	—	—	25
Total	1,012	100.0	855	115	42
Percentage	100.0	—	84.5	11.4	4.1

Table 1 shows the age, sex, and residence of the anglers. Residents are considered as all persons eligible to fish with a New York State resident's license. Chautauqua Lake, being located near the western part of the State, draws rather heavily from Pennsylvania and Ohio. If the instances in which the residence is not reported are distributed proportionately among the residents and non-residents, results indicate that approximately 88 per cent of the anglers are residents of New York State. Elkins (1937) found that 88 per cent of the anglers fishing in the Chequamegon Forest in Wisconsin were residents of Wisconsin. Eschmeyer (1937), on the other hand, found that only 65 per cent of the anglers fishing at Fife Lake, Michigan, were residents of Michigan.

Table 2 shows the type of fishing and Table 3 the type of bait used by the fishermen.

TABLE 2. TYPE OF FISHING

Type of fishing	Number of reports[1]	Percentage
Still-fishing	482	47.6
Trolling	312	30.8
Casting	248	24.5
Shore or wading	25	2.5
Other	11	1.1
Not reported	103	10.2
Total	1,012	100.0

[1]Includes reports indicating two or more types of fishing; the total represents individual reports.

A high percentage of the fisherman-days, 1,214 days or 81.6 per cent, represented completed days of fishing at the time each report was made out. These fishermen spent a total of 5,782 hours, or an average of 4.8 hours per day per fisherman. The number of hours per day spent in fishing, reported by other investigators, is as follows: Needham (1937) California trout-lake, 4.3 hours; Elkins (*op. cit.*) 4 hours; Eschmeyer (*op. cit.*), 2.5 hours. The higher aver-

age reported for Chautauqua Lake may be partly due to the fact that the census was taken at a time when the days were longer; the data for other lakes are based on information for the summer. It is possible that daylight-saving time, which is used on Chautauqua Lake, may also affect the data since it allows more time for fishing in the evening.

TABLE 3. TYPE OF BAIT USED

Type of bait used	Number of reports[1]	Percentage
Plug	377	37.3
Worms	306	30.2
Crayfish	260	25.7
Spinner	177	17.5
Minnows	154	15.2
Fly	10	1.0
Other	4	0.4
Not reported	58	5.7
Total	1,012	100.0

[1]Includes reports indicating the use of two or more types of bait; the total represents individual reports.

The characteristics of the fishing effort on Chautauqua Lake during the period under investigation may be stated as follows: the fishing was carried on chiefly from boats by still-fishing and trolling and casting with artificial lures (plugs and spinners) and live baits (worms and crayfish); each boat contained, on the average, 1.8 fishermen, and each fisherman spent, on the average, 4.8 hours in fishing.

Analysis of the Catch. Table 4 shows the number of legal fish

TABLE 4. CATCH OF LEGAL FISH

Species of fish	Total catch[1] Number	Total catch[1] Per cent	Catch in northern end of lake Number	Catch in northern end of lake Per cent	Catch in southern end of lake Number	Catch in southern end of lake Per cent
Smallmouth bass	284	7.6	193	15.1	51	2.3
Largemouth bass	212	5.7	71	5.6	126	5.7
Muskalonge	80	2.1	49	3.8	26	1.2
Bullheads	159	4.3	62	4.8	84	3.8
Common sunfish	1,528	40.9	342	26.8	1,157	52.3
Yellow perch	648	17.4	195	15.3	397	17.9
Rock bass	539	14.4	315	24.7	193	8.7
Bluegill sunfish	198	5.3	36	2.8	152	6.9
Common or bluegill or hybrid sunfish	49	1.3	2	0.1	6	0.2
Calico bass	30	0.8	13	1.0	16	0.7
Log perch	4	0.1	—	—	4	0.2
Carp	1	0.1	—	—	1	0.1
Total	3,732	100.0	1,278	100.0	2,213	100.0
Pan fish[2]	2,997	80.3	903	70.7	1,926	87.0

[1]The total catch includes 241 fishes which were not segregated into north or south localities.

[2]Pan fish here includes log perch and carp but not bullheads.

taken during the five-day period, and gives comparative figures for the north and south ends of the lake. In this segregation, it is of interest to note the ecological preferences shown by the various species. The preponderance of largemouth black bass, bullheads, common sunfish, bluegills, and yellow perch in the shallow, weedy, mud-bottomed, south end is statistically significant. The north end, characterized by deeper water, fewer weeds, and a greater percentage of hard bottom, is evidently more favorable for smallmouth black bass and rock bass. The total number of muskalonge taken was highest at the north end, which is more suitable for trolling. Success of fishing per unit of effort was slightly better in the south end, however, as the take of muskalonge per trolling-hour was only 0.046 for the north end as against 0.087 for the south end.

In addition to the 3,732 legal fish recorded in Table 4, the following fish were reported as being returned to the water: 5 muskalonge (22 to 24½ inches), 111 smallmouth bass (6 to 11 inches), 38 largemouth bass (8½ to 10 inches), 18 bass, species not indicated, 6 bullheads, 15 sunfish, including bluegills, 64 yellow perch and 17 rock bass. It is believed that the identification of fish returned to the water was not always reliable, and that such fish were not reported in many instances. These figures are not given in the table. Such data, however, are of great importance in evaluating the biological status of the various fish populations, and the results point to the necessity of drilling the census-takers in obtaining this information.

Eighty per cent of the total number of legal fish recorded were pan fish, with the smallest of these, common sunfish and yellow perch, most abundant. It should be mentioned here that the percentage given for calico bass is undoubtedly too low to be representative for the whole year, since highly successful fishing for this species is experienced regularly during early May. If the large Chautauqua Lake bullhead is included with the pan fishes, as the species would ordinarily be treated in other waters, this would bring the percentage of pan fish up to 84.6. Of the three large game fishes caught,

TABLE 5. RELATIVE PROPORTION OF GAME FISH AND PAN FISH IN THE CATCH AT CHAUTAUQUA LAKE AS COMPARED WITH FIFE LAKE, MICHIGAN

Species of fish	Percentage		
	Chautauqua Lake 1937	Fife Lake 1934	Fife Lake 1935
Smallmouth bass	7.7	9.3	6.9
Largemouth bass	5.7	2.8	4.1
"Pikes"[1]	2.2	1.6	1.8
Pan fish[2]	84.4	86.3	87.2

[1]Includes muskalonge from Chautauqua Lake; northern pike and wall-eyed pike from Fife Lake.

[2]Includes sunfish, bluegills, rock bass, perch, and bullheads.

the smallmouth slightly outnumbers the largemouth bass, whereas the muskalonge contributes only 2.1 per cent of the total number of fish caught. These figures are closely comparable with percentages for the same classification of the catch from Fife Lake, as reported by Eschmeyer (1936 and 1937). The comparison of the percentages is shown in Table 5.

An important calculation, from the management point of view, is the yield of fish per unit of fishing effort. The catch per fisherman-hour and the average number of fish per angler per day are shown in Table 6. Of the number of fisherman-days reported, 45.9 per cent had no catch of legal fish. The average number of fish per fisherman-hour for Chautauqua Lake was 0.55. This value may be compared with that obtained for other sport fisheries as follows: Elkins (1937) records the average number of fish per fisherman-hour from four Wisconsin lakes as 0.81; Eschmeyer (1936 and 1937) gives the catch per fisherman-hour for Fife Lake as 1.72 fish in the summer of 1934 and 1.27 fish in the summer of 1935; Needham (1937) reports the catch for a California trout-lake as 0.21 trout per fisherman-hour; Mottley (1938) reports the catch in a five-year average for a British Columbia trout-lake as 0.77 fish per fisherman-hour.

TABLE 6. FISH PER HOUR AND FISH PER ANGLER PER DAY

Species of fish	Average fish per hour	Average fish per angler per day
Smallmouth bass	0.040	0.19
Largemouth bass	0.030	0.14
Muskalonge	0.012	0.05
Bullheads	0.023	0.11
Pan fish	0.440	2.01
Total fish	0.550	2.50

The value given for Chautauqua Lake is apparently rather low when compared with other sport fisheries. It may be low as a result of factors other than a scarcity of fish at the time of the census. Possible explanations of the low yields are (1) an unusual number of inexpert fishermen during the holiday period, (2) concentration of fishing for muskalonge which would normally produce lower returns owing to the low incidence per hour for this species, and (3) unfavorable weather on the first two days of the period. The catch per hour for the five days was as follows: July 1, 0.27; July 2, 0.40; July 3, 0.75; July 4, 0.63; July 5, 0.60.

With regard to the catch of muskalonge per fisherman-hour given in Table 6, this value represents the number of muskalonge divided

by the total number of fisherman-hours. Hence, fishing effort confined to other species makes this figure much lower than it would have been if computed only from effort employing muskalonge tackle. At the time of taking the census muskalonge was the principal fish caught by trolling and this was also the only important method of fishing for it; later in the year, however, the fishermen use live bait. Therefore, a better index of the catch of muskalonge for this period would be the number of fish per trolling hour (Table 7). The catch of muskalonge per trolling hour was 0.054 fish. This is more clearly expressed as approximately 18 hours of trolling to catch one muskalonge. Similar values could be worked out for the other species if it were known what species of fish each fisherman was trying to catch. Where mixed populations of fish are present, it would probably be much better to adopt a unit of effort based on the type of fishing employed or the species being sought. The designation of the catch per unit effort would then be stated in terms of trolling, casting, or still-fishing hours.

TABLE 7. DATA ON THE DAYS AND HOURS OF TROLLING AND CATCH OF MUSKALONGE FOR THE FIVE DAYS OF THE CENSUS

Date	Number of fisherman-days' trolling	Number of trolling hours	Number of muskalonge caught	Number of muskalonge per trolling hour
July 1	64	317	13	0.041
July 2	25	77	10	0.130
July 3	59	264	18	0.068
July 4	77	322	22	0.068
July 5	67	331	8	0.024
Total	292	1,311	71	0.054

Whether there is a proper balance between the various populations of fish in the lake cannot be settled by the census alone. In a lake of this size and depth there may be a high proportion of pan fish species, because pan fish, other than the calico bass, have a smaller average size than is usually found, whereas the bass and muskalonge appear to be exceptionally large. The muskalonge that were opened possessed unusual amounts of fat; and 4-pound bass were relatively common. These points need further checking by studies of the scale series and repeated census work over a period of years. The average size of 221 smallmouth bass was 12.61 inches, of 206 largemouth bass 12.87 inches, and of 71 muskalonge 32.3 inches. The data for the bass compare favorably with those for Fife Lake reported by Eschmeyer (1937). Further data will be needed before it can be determined whether the game fish populations in Chautauqua Lake are showing signs of depletion.

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NOTES ON THE INTRODUCTION OF *SALMO NELSONI* EVERMANN INTO CALIFORNIA FROM MEXICO[1]

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ABSTRACT

Through the courtesy of the Mexican Government, fifty yearling *Salmo nelsoni* were introduced into California from the Santo Domingo River in Lower California, Mexico, in May, 1937. The chief reasons for the selection of this species of trout for experimental brood stock purposes are (1) the need of developing a non-migratory type of trout for planting, (2) the advisability of starting with a brood stock selected from a pure, wild strain which has been prevented by barriers from migrating to the sea over a long period of years, and (3) the high temperature tolerance shown by this trout in its natural habitat.

A brief history of the species is given. A distinct hump on the back, directly above the preopercle at the base of the head, hitherto not described, is suggested as a character by which *S. nelsoni* may be distinguished from other members of the rainbow series found in the coastal waters of California.

Fifty trout, *Salmo nelsoni* Evermann, ranging from 5 to 9 inches in length, were introduced into California from the Santo Domingo River on the Peninsula of Lower California, Mexico, in late May, 1937. This species of trout was selected with the object of developing if possible a non-migratory strain of rainbow trout for planting in California waters.

In May, 1936, the writer accompanied by Mr. F. W. Johnson of the U. S. Forest Service made a reconnaissance trip via truck and horseback to the Santo Domingo River to determine the feasibility of collecting and transporting *nelsoni* alive back to California. Good paved roads were found from San Diego to Ensenada, Mexico, a distance of about 87 miles. South of Ensenada a very poor dirt road led 150 miles south via Santo Tomas, San Vincente, Arroyo Seco, and San Telmo to Valladares. From this point a 10-mile pack trip by trail was necessary to reach the main Santo Domingo River at the Rancho San Antonio where the trout occur. Thirty preserved specimens were secured on this trip and plans were laid for a later attempt to obtain a stock of these fish alive. Accordingly, in late May, 1937, after receiving official permission from the Mexican Government to collect the trout, and after careful advance preparations to care for the fish, a second trip was made and the fish mentioned above were secured. These fish, if they survive, will serve as a nucleus from which it is planned, for reasons given below, to develop a future brood stock of this strain of trout.

In many states, downstream migration of trout often causes heavy losses annually due both to irrigation and power diversions. It may

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not be possible to find a non-migratory type of rainbow; but at least by starting with a strain, such as *Salmo nelsoni,* which has been forced by both climatic and geographic barriers to forego downstream migrations for centuries, the chances of developing such a trout seem fairly good. Natural selection operating in nature over a long period of time would probably assist in the production of just such a type of fish. Further, in order to start with an absolutely pure strain of trout, that is, one in which no cross breeding had occurred with planted hatchery fish, it seemed best to go outside California. Indiscriminate hatchery plants have so mixed up various strains of both native and introduced trout that in many instances native populations have been completely modified or changed from their original character.

All salmonids are more or less migratory. Periodic migrations between feeding and breeding areas are well known. Some are more migratory than others, however, for the steelhead or sea-run type of rainbow will migrate hundreds of miles whereas inland, resident forms may merely migrate only a few miles from streams to tributary or from lake to tributary, in order to spawn. Their migratory habits have long been a sore spot with fish culturists. The similarity in appearance and the differences in migratory habits of members of the rainbow series, have inevitably resulted in much indiscriminate breeding and mixing of strains through propagative efforts.

Many articles abound in fisheries literature regarding attempts to establish rainbow trout in waters where they were not native. One eastern fish culturist used to plant his legal rainbows in the fall until it was reported that many were being caught in shad nets in coastal streams enroute to the sea. He now plants in the spring trusting that most of them will be caught by anglers prior to their departure seaward. Other records show that frequently rainbows, when planted in streams to which they are not native, remain there, reproduce, and maintain themselves in sufficient quantities to furnish much good sport. Lord (1935) reports with regard to the Furnace Brook "Test Stream" in Vermont, that rainbows made up 34 per cent of 8,500 legal trout caught in the season of 1935, and that rainbows are not stocked in this stream but hold their position entirely by natural spawning. Reports from other workers have also shown that native species are maintaining themselves in many streams in spite of the fact that largely non-native forms are planted from year to year. It seems evident that a careful study of the hereditary background of hatchery brood stocks, as related to migratory habits and temperature tolerances, would make it possible to plant the offspring of such hatchery fish in waters where their best possible utilization by anglers would be obtained. Selective breeding of trout has already greatly increased the possibilities of hatchery production. But will such fish when planted

Fig. 1.—Freshly caught *S. nelsoni.* The two lower specimens show the distinct hump directly above the opercle at the base of the head. Photo by courtesy of Mr. Everett Horn, U. S. Biological Survey.

Fig. 2.—Typical stretch of the Santo Domingo River near the Rancho San Antonio inhabited by *S. nelsoni.* Note white granitic sand bar at left deposited by heavy floods. Photo by courtesy of Mr. Everett Horn, U. S. Biological Survey.

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in streams increase the angler's production? The adaptability of domestic strains of trout to hatchery life does not necessarily prove that their offspring will be equally well-suited to stream life. The behavior of fish *after* planting is more important than that *before* planting.

Steelhead have been crossed with the so-called Shasta rainbow of early-day fish culturists; cutthroat have been crossed with rainbow and steelhead; rainbows with golden, and so on, until today it is pretty much anybody's guess what the genetic constitution is of most hatchery-reared brood stocks.

An attempt was made in 1933 to obtain the San Gorgonio trout, *Salmo evermanni* Jordan and Grinnell, another member of the rainbow series, from the streams at high elevations on Mt. San Gorgonio in the San Bernardino Mountains in Southern California. Assiduous collecting, however, showed that planted stocks had interbred with *evermanni,* therefore they were not selected for the experimental work herein outlined. Obviously in planning work of this kind it is of prime importance that a trout be selected in which there had been no possible chance of cross-breeding with planted stocks. Great value would result if the migratory and other habits of parent stocks from which eggs are taken were determined by carefully planned and executed experimental work. The offspring from brood stocks of known genetic backgrounds could then be planted in waters to which they were best adapted in the light of their migratory habits and adaptability to water temperatures or other conditions.

Salmo nelsoni was first collected in 1905 by E. W. Nelson, former Chief of the Bureau of Biological Survey, U. S. Department of Agriculture, during an extended exploration trip through the Baja California Peninsula. The specimens were turned over to Dr. B. W. Evermann, who described them as new (Evermann, 1908) and who named the species *nelsoni.* Nelson (1922) recorded briefly the fact that the trout were collected from the Santo Domingo River near the Rancho San Antonio and gave a few notes on the character and type of waters from which they were collected. Chester Lamb of the Museum of Vertebrate Zoology of the University of California, again collected *nelsoni* from the same locality in 1925. His specimens were turned over to Dr. J. O. Snyder for study who (1926) gave a detailed comparison of these fish with several other members of the rainbow series.

As noted both by Evermann (1908) and Snyder (1926), *Salmo nelsoni* closely resemble typical rainbows in general appearance and definitely belong to the rainbow series. Evermann considered these fish most closely related to the Kern River trout and the various species of golden trout of the Kern River region. Snyder concluded that *S. nelsoni* closely resemble *S. irideus* from coastal streams but did not give any clear-cut characters by which they could be distin-

guished. He stated, however, that *S. nelsoni* "are somewhat more deep, heavy and less trim, the caudal peduncle is deeper, the caudal fin perhaps less deeply notched, the head longer and somewhat blunter, the eye much larger, and the fins somewhat stronger. These very characters are subject to much variation in *S. irideus* however." (*Loc. cit.*, p. 26.)

One very peculiar structural character not mentioned by earlier workers is the presence of a distinct hump on the back of the fish directly above the preopercle at the base of the head. (Figure 1.) This hump gives most of the specimens collected a somewhat hump-backed appearance. Practically all of the thirty specimens (measuring from 1¼ inches to 9 inches) that were collected and preserved on the 1936 reconnaissance trip have a hump-backed appearance. It was also evident in freshly captured individuals so it could not have been due to preservation in the formaldehyde solution. The nine specimens preserved on the 1937 trip ranged from 8 to 9 inches in length and the hump was not nearly so evident. Careful measurements of the body proportions of all specimens collected will be made to determine the extent and range of differences in this and other characters in comparison with other members of the rainbow series from California coastal waters.

Another peculiarity seen in a few of the living specimens was the presence of scar tissue that formed a narrow, whitish-grey streak or band from the rear top surface of the head to the dorsal fin. Of the fifty living specimens transported north, only one clearly showed scar tissue. Several others were seen in the stream that had conspicuous scars on their dorsal surfaces. Several of the larger preserved specimens also show some evidences of such scar tissue.

The abrasive action of granitic sand and gravel carried by heavy floods in the Santo Domingo River during the rainy season probably accounts for the scar tissue seen on the dorsal surfaces of these trout. Constant rubbing against rock crevices or under ledges when seeking protection from heavily laden flood waters would also tend to abrade the skin, thus causing the later formation of scar tissue. Nelson (1922, p. 22) stated, "The people at San Antonio Ranch reported that trout were much less numerous than usual in 1905, owing to tremendous floods which had swept down the canyon the year before, carrying so many boulders that many trout were killed." Evidences of heavy floods during the winter of 1936-37 were also plainly visible. Debris caught in the branches of willows and other plants at the edge of the stream could be seen 6 to 8 feet high above the stream bed. White granitic sand carried from the mountains had formed large bars at the sides of the stream and in the pools (Figure 2). Many pools had been completely filled with debris, and stretches several hundred yards long were wide and shallow with no shelter whatsoever for trout, since the original stream bed had been

covered with and almost completely levelled by granitic sand. Adequate vegetative cover to hold the soil in place and to aid in prevention of rapid run-off of rain water was lacking and this condition was undoubtedly a major factor that contributed to the severity of the floods characteristic of the Santo Domingo River drainage.

Observations of the trout present in the stream in 1936 as compared to 1937 gave further evidence of the effect of floods on *S. nelsoni.* In May, 1936 fingerlings from 1¼ to 3 inches long were quite abundant and specimens apparently in their second year, ranging between 4 and 7 inches, were relatively scarce. In May, 1937 only two small fingerlings an inch or so in length were seen while yearlings from 5 to 9 inches long were fairly common, though not as abundant as one would have expected after observing the large number of young fish in the stream in 1936. Evidently heavy floods in 1936-37 had destroyed most of the fry and fingerlings hatched in the spring of 1937 along with a goodly portion of the yearlings hatched in 1936.

The Santo Domingo River, in that section where *S. nelsoni* was found in May, 1936, was flowing about 4 cubic feet per second and averaged from 12 to 15 feet in width. A small tributary, Santa Cruz Creek, that joins the main stream about one-quarter mile above the Rancho San Antonio, contributed about one-third of the total flow. In May, 1937 the flow in the main river totalled approximately 6 cubic feet per second while Santa Cruz Creek contributed about one-fourth of this amount. Most of the trout netted alive for transportation north were taken from Santa Cruz Creek since they were scarce in the main river near the Rancho San Antonio. Floods are evidently much more severe in the main stream than in Santa Cruz Creek. Those of the winter of 1936-37 had greatly reduced the trout population of both streams, as noted above.

We had hoped to obtain from three to four hundred small fish of the year but their scarcity made it necessary to take fewer but larger yearlings. From observations made on the two trips to the Santo Domingo River, it seems probable that *S. nelsoni* spawns in January or February. The comparatively early season is no doubt due to the southerly latitude of the stream.

Both Evermann (1908) and Snyder (1926) stated that in all probability the Santo Domingo River was stocked with trout by natural extension from trout waters of the coast region of Southern California, the trout passing southward through the sea from stream to stream at a period when climatic conditions were favorable. Undoubtedly, once these fish became established in the river they continued periodic migrations to and from the ocean as long as climatic conditions remained favorable. However, climatic barriers that occurred since that time stranded these fish in about 7 miles of stream in the mid-portion of the river some 35 to 40 miles

from the ocean. On the 1936 trip, the writer visited the mouth of the stream and found a high sand bar blocking the mouth with only stagnant, standing pools of water at scattered intervals along its course over the flood plain. No water was flowing into the ocean. Signs that it does flow into the ocean during flood periods were quite evident. From inquiries made at neighboring haciendas on the lower river, no reports whatever were obtained regarding the presence of migratory fishes in the lower river. Sticklebacks were abundant but no young trout were either seen or collected. Natural selection, working over a long period of years since the establishment of trout in this stream, would have tended to eliminate, by excessive water temperatures and other unfavorable conditions in the lower river, those fish that attempted to migrate to the ocean. The question of importance is, "Would offspring from such stock revert to their age-old migratory habit and go to the ocean if planted in waters giving easy, safe access to it?" Obvioulsy, only experimental plantings carefully conducted will give the answer to this question.

S. nelsoni might prove useful to fish culture for another reason—adaptability to excessive water temperatures. No water temperatures of the Santo Domingo River were recorded by earlier collectors. Snyder (1926) stated that, according to Lamb, the water becomes quite warm at times.

The writer found a water temperature of 76° F. at 1:15 p.m. on May 17, 1936 in the main river at the Rancho San Antonio where the trout occur, when the air temperature was 81° F. Santa Cruz Creek showed a somewhat lower temperature of 71° F. at 2:35 p.m. on the same date. Similarly, a year later on May 23, 1937 a water temperature also of 76° F. was found near the same point in the main stream. Records taken in the early morning at 4:00 a.m. on the 1937 trip showed a temperature of 60° F. in the main stream. Thus a daily fluctuation of at least 17° F. was evident in the month of May. These temperatures show that the water becomes quite warm early in the season. In late summer and early fall during periods of minimum run-off and maximum air temperatures, water temperatures must go well over 80° F. in the main stream near the Rancho San Antonio. Some escape from excessive temperatures would be afforded the trout by migration upstream to cooler water. However, they would be stopped in the main stream by impassable falls within 5 miles upstream above the Rancho San Antonio. The valley through which the river flows is steep-sided, deep, rocky, and hot. Giant cactuses and other typical desert plants abound close to the canyon floor. The banks of the stream are partly covered by a scattered growth of live oaks, sycamores, and willows that afford some shade from the sun's rays.

In connection with the temperature adaptability of *S. nelsoni,* it should be stated that the fish that were netted and transported north on the 1937 trip stood a maximum water temperature of 80° F. with-

out apparent harm. However, this temperature was taken when the fish were being "rested" in a cage in Valladares Creek at the end of the road, after they had been packed out on horseback from the river and prior to the trip by truck north. From these observations it seems likely that these fish might show considerable adaptation to excessive water temperatures. Here too, only experimental work with the offspring will reveal their actual tolerance with regard to this factor.

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Discussion

The President: Is there any discussion on the paper just offered by Dr. Needham?

Dr. Langlois: That is a very interesting paper by Dr. Needham dealing with a species of known migration. I would like to discuss this briefly in reference to our native Ohio smallmouth bass to illustrate the point. In Lake Erie the smallmouth bass moves in the spring up the streams in Ohio and returns to the waters in Lake Erie after having spawned, and the young remain up stream; remain there and grow and seem to constitute a large population in these up-stream waters. In our rearing ponds at the State Fish Hatcheries we are producing this same species and when we place them out in natural waters where they produce young we find that the individuals produced in our fish ponds invariably show a down-stream migration when liberated into the streams

where current conditions prevail. Whether or not this is a sympathetic reaction to the current we do not know. However, we are not at all sure that this is the only factor involved. We know that when we confine a 4-inch smallmouth bass fingerling to the limited habitat prevailing in an aquarium and later liberate in that same aquarium a 6- or 8-inch bass, the bass which first occupied those waters and had developed there will in a short space of time effectively eliminate his rival and it may be that the addition of hatchery-produced fingerlings to an entirely strange habitat in a stream means simply turning loose a stranger in an unaccustomed environment where he is driven by the fish already present to move from place to place until he finds a place where he can remain. So the stocking of a California stream with this species of fingerlings, produced under artificial conditions, should be tested by subjecting these fish to careful restrictive conditions in the environment so that they may definitely be established without an opportunity first to move down stream.

THE BENEFITS OF INTERNATIONAL COOPERATION IN FISHERY RESEARCH

FRANK T. BELL
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Our three countries—Canada, United States and Mexico—have been neighbors for more than a hundred years. Our people have enjoyed one another's hospitality and culture, and have gone back and forth across our borders all these years. It seems a long time to us. But that time is nothing compared to the thousands and thousands of centuries that our fish have been neighbors. How many years have the tunas, the swordfish, the barracudas, the tarpon and the turels migrated up and down the coast of the Americas? Long before there were any men at all on the earth.

So it is appropriate that this Society should be as cosmopolitan as those creatures it studies. For the past seventeen years, the American Fisheries Society has divided its meetings between the United States and Canada, and it is high time we extended the range of our meetings into Mexico. If fishing trends continue in the same direction they have been following for the past ten years or so, I predict we will have to be ever more and more cosmopolitan as time goes on.

As I look back over the history of the Society since its beginning, it seems to me that there are three events that stand out above all the others as marking turning points in the progress of fishery science. The first of these events occurred in 1885, during the eleventh meeting, when the organization changed its name from the American Fish Culturists' Association to the American Fisheries Society, and revised its constitution. Before that time, it had been concerned exclusively with the promotion of the cause of fish culture, but at that meeting, the Society broadened its interests to include all fishery questions of a scientific or economic character.

The second great event occurred in 1920, fifty years after its founding, when the Society met in Canada for the first time. Although we had always been more or less international in our interests—we had members from Mexico, from Canada and from various countries of Europe—yet that was the first meeting we had ever held outside the United States. That meeting marks the beginning of modern international cooperation in fishery research in America, for it was not long afterwards that the International Commission, representing both the United States and Canada, was established to study and control the halibut fishery.

Now we are having the privilege of witnessing the third of those three greatest events in the distinguished history of the American Fisheries Society—the first meeting in Mexico. I have every confidence and hope that this meeting will prove to be another milestone

in the path of advancement in the aquatic and marine sciences of the western hemisphere, that it will mark the beginning of a closer cooperation between the United States, Canada and Mexico in fishery matters.

It is interesting to me, as I read over the old transactions of this Society and the history of aquatic and marine resources of America, to note how events have changed fishery science. In 1871, when the first meeting was held, everyone knew exactly what to do to save a depleted fish population—propagate more fish! All of the papers read at that meeting had to do with fish propagation. How simple were the problems of conservation in those days compared with today!

We can take the halibut fishery as a very good example of the effect of changing times on conservation problems. In 1871 there was no halibut problem on the Pacific Coast. There was, in fact, no commercial halibut fishery at all until 1880. Fishing in those days was carried on by the early Canadian and American settlers only in small sail-boats, and the total catch was so small as to be scarcely worth mentioning its quantity in our statistical tables.

Yet the fish were very plentiful; hardly would a fisherman get a baited hook to bottom before there was a fine big halibut on it, sometimes weighing two or three hundred pounds. There were plenty for everybody. So the settlers wrote east to their friends, and by 1890 a fleet of sailing boats had started a halibut fishery in earnest. I remember when that occurred; so do many of you. I remember how plentiful halibut was; how you could buy it in the market for only 5 cents a pound (it sells for 30 or 40 now); and how in only a few years, those boats, Canadian and American, had depleted their local grounds almost to the point of exhaustion. It is true there were still plenty of halibut to the north, but those boats were not equipped for continued high seas fishing.

As time went on, however, vessels were made larger and more efficient, and the fishery grew enormously productive, until in 1915, Canadian and American vessels caught 69,000,000 pounds of halibut.

Then about 1918 came the realization that the consequences of unwise fishing were at hand, that we were faced with stark depletion, and had no new grounds left to explore. It is amazing that this rise and decline of a great industry should occur in the very brief span of our own memory! What could be done to restore this industry? It was an international fishery, followed alike by Canadians and Americans. The fish themselves were international, migrating back and forth between the two countries, without respect for boundaries or national laws. And so a joint fisheries commission for the study of the Pacific halibut was formed in 1923 by international convention between the United States and Great Britain in respect to Canada—the first treaty in the history of the world designated to save a high seas fishery.

It took time, of course, to learn what could be done about the situation. Scientists of the International Commission proceeded with a painstaking study on the biology and abundance of the halibut. During this interval, the efficiency of fishing vessels improved still more. New equipment permitted ships to fish in deeper water, and at greater speed than ever before. But for all this improvement in methods, and for all the increase in demand, the catch did not increase, so that in 1925 it took six times as much gear to catch the same quantity of fish that was taken in 1906.

By 1931, however, the fishery scientists had built up a fund of necessary information about the halibut, and they were ready to recommend a program of scientific and economic control. Consequently, that year, a new treaty was adopted fixing limits to the total catch permitted in a year, based on those recommendations. How successful has this program been? After six years of such management, the Commission reports a steady and marked improvement in the condition of the fishery. There are more spawning adults, more eggs spawned, a general increase in abundance, and what is most impressive, the catch per unit of effort has almost doubled.

Now that is a record that speaks for itself. There is a clear case where international cooperation has resulted in the wise and sound economic management of a great fishery resource. Such a record would have been utterly impossible if either the United States or Canada had attempted this management independently of the other.

The history of the sockeye salmon fishery of the Fraser River is even more dismal than that of the halibut. Probably no other fishery in history ever developed in so short a time, ever reached such a wealth of production, or ever declined so rapidly to the low ebb of depletion. At the height of its yield in 1913, this fishery produced nearly eleven million dollars for American packers; by 1936 it produced little more than $800,000, though the price of salmon had doubled.

It is all too evident that this great fishery, which had caused alarm for its condition as early as 1897, is now threatened with complete exhaustion. Such a condition threatens a severe economic blow to the State of Washington and the Province of British Columbia, and one which the United States and the Dominion of Canada can ill afford to suffer. It is an unnecessary blow, however, for the fishery is not yet so exhausted that it cannot recover.

Any regulations designed to restore and perpetuate the sockeye population on the Fraser River must of necessity require the coordinated efforts of both Canada and the United States. Accordingly, only last month formal ratifications were exchanged for a convention between the United States and Canada for the protection, preservation and extension of the sockeye salmon fisheries of the Fraser River system.

With this treaty as an assurance of mutual cooperation between the two countries in the task before them, and with a sound program of scientific research to keep administrators abreast of the changing status of the fishery, we can feel certain that this international river will in time again return an economic harvest to our fishermen.

On our North Atlantic coast we have another species of international importance—the haddock. It, too, is in a state of relative depletion, and it, too, needs international cooperation in the control of its fishery. For several years the U. S. Bureau of Fisheries has carried on an investigation of the haddock fishery. After much experimenting, our biologists found that an enormous amount of wastage of small unmarketable fish could be eliminated by the use of larger mesh in the otter trawls. Although many vessels have adopted this gear in accordance with our recommendations, there are many more ships that continue to use the small mesh, and consequently to destroy vast quantities of small fish.

To get effective, coordinated and continued action in this matter, we must establish legal regulations. But to be of most benefit to the fishery, these regulations must be applied to trawlers of all the nationalities which frequent the fishing banks where haddock live. This will require the cooperation of the United States and Canada. These are the two countries chiefly interested in the New England and Nova Scotia Banks. The North American Council on Fishery Investigations has recently recommended the drafting of an international treaty to require the use of nets with larger mesh. If such a treaty were adopted, we could feel much safer than we do now about the future of the haddock fishery, and the continued livelihood of haddock fishermen.

I think I can safely say that practically every one of the fishery problems of America requires inter-governmental cooperation of one kind or another. In the United States, where we have forty-eight separate state governments, we must have agreements and pacts and cooperation among groups of states before many fisheries, sport or commercial, can be effectively managed.

We have good reason to know how profitable cooperation between the states in conservation matters can be. Until six years ago, the black-bass laws in the United States were in a condition of chaos. Some states permitted commercial fishing for the black bass; others prohibited it. Some states imposed closed seasons; others had none. Some states imposed size limits that ranged up to 11 inches; others imposed none. Because of this confused situation, it was very hard for individual states to enforce their black-bass laws. Then in 1931, the Hawes Black Bass Law was placed under the jurisdiction of the Federal Bureau of Fisheries, and we at once set to work toward coordinating the various conflicting laws, and toward bringing the laws to a high standard of conservation effectiveness. I said that six years ago the black-bass laws were in a state of chaos. Thanks to coordi-

nated action between state and federal governments, that statement is not nearly so true today; and though we still have a long way to go, we are making continual and steady progress toward an effective management of our black-bass sport fishery throughout the United States.

We have in the states an organization devoted exclusively to achieving cooperation. The National Planning Council of Commercial and Game Fish Commissioners was organized in 1934 to coordinate the fishery conservation work of the state and federal governments, to achieve maximum fish production at minimum cost, to apply efficiency methods in the distribution and planting of fish, and to exchange information of common interest and value to fish culturists. Among the chief benefits of this institution has been the elimination of much of the duplication and overlapping in fish distribution activities.

A condition more in need of inter-state action than anything else today in the United States is the appalling pollution of our streams and lakes. Chemical wastes from factories, sewage from cities, silt from denuded soil, pour into too many of our streams, making the water not only unfit for human use, but uninhabitable to fish and other aquatic life. This situation is not one in which the federal government has jurisdiction, and it is therefore up to the individual state governments to prevent their streams from being transformed by pollution into barren aquatic deserts. But if one state does pass laws correcting the pollution of its rivers, of what benefit will that be if neighboring or even distant states continue polluting those same rivers? It is for that reason that the correction of pollution hazards has not made greater headway, and it is not until neighboring states get together and cooperate in the study and control of their mutual pollution problems that this evil will be finally and permanently ended.

We have many other problems in fisheries conservation, in need of interstate or international action. There are many fisheries, especially on our sea-coasts, that remain virtually or entirely unprotected by state laws, and as a consequence are faced with eventual depletion. The shad on the Atlantic coast is a notable example. In the 1890's, as many as 50,000,000 pounds of these fish were caught in a year by commercial fishermen. Today, as a result of obstructions in rivers, of pollution, and of over-fishing, less than one-fifth as much is taken. If this species is to be restored to a safe level of abundance, all the states on the Atlantic seaboard into whose rivers the shad run will have to work together to that end.

Along our north Atlantic coast south to New Jersey, we have a lobster population exploited by the fishermen of eight states. We all know the lobster is growing scarcer every year, that at the present rate of fishing it will eventually become such a rare animal it will hardly pay fishermen to go after it. Such a situation

is altogether unnecessary. The lobster fishery is one that should be unusually responsive to sound management. Yet for economic and biological reasons, no program can be successful without the coordinated efforts of all the governments to whom the lobster fishery is valuable. I hope such coordinated effort will be forthcoming before it is too late.

On the west coast of America is another lobster, which is found all the way from southern California down to the southern tip of Mexico. It is mostly a Mexican fishery, somewhere around a million pounds being taken here for local and foreign markets each year. Like many good creatures of the sea, however, this spiny lobster is very evidently headed toward depletion. Native fishermen have to work harder and harder to catch the same quantity of lobsters every year. About one-third of the total catch of these animals comes from waters of the United States. This fishery is therefore international, and it is to the interest of fishermen both from the United States and from Mexico to sustain the population of spiny lobsters so as to insure a continued production. We look forward to the day, when international cooperation between our countries will make possible a program of scientific management of the fishery.

The Pacific sardine or pilchard is a prime example of a fish with international distribution, for it ranges all the way from Alaska down to the Gulf of California. More pounds of pilchards are caught than of any other species of fish in the western hemisphere. More than a thousand million pounds of them are taken every year! That is a good many fish; yet the industry shows every sign of expanding still more. It is very doubtful that such a huge exploitation can go on indefinitely without endangering the very existence of the species. It is possible that the symptoms of depletion may come on insidiously and appear suddenly to spell ruin to the entire industry. It is far better to invest in a sound program of scientific research on the fishery now with a view to preventing depletion, than to wait until the dread symptoms have appeared and it is necessary to cure it. The prevention is much less painful and less expensive than the cure.

Now there is reason to believe that Pacific pilchards migrate considerable distances and that any program of scientific study of this species with a view to the eventual management of the fishery, must be international in scope, carried on in a united front by Canada, the United States and Mexico.

Another example of commercial fish with international distribution is given by the tunas. The tunas of the Pacific coast support one of the most valuable fisheries of the world, and provide a living for fishermen from southern California down to northern South America. In spite of the value of these fishes to the nations of North and Middle America, our knowledge of them is practically a blank. If we in this meeting suddenly received word that the tuna

season this year had proved a dismal failure and that there was every sign of exhaustion of this splendid resource, we would not know what to do about it. There is no fishery on either Atlantic or Pacific coast so much in need of scientific study as that for the tunas, and there is none for which such a study would require so much wholehearted international cooperation.

I could go on giving examples like these for a long time. I could tell you about the fishes of the Great Lakes, about the mackerel, the flounders, the weakfishes, the marlins—all diminishing in number for want of inter-governmental action. If the fishermen of Canada, the United States and Mexico are to continue to earn their living, and their children and their children's children are to be assured of earning their living as fishermen, and if the sea is to continue to produce food for our people, then our three governments must work together for that common purpose. I can think of no more valuable thing for this Society to do, than to exert its efforts toward achieving such cooperation.

Discussion

The President: Are there any questions or comments on the paper just presented by Commissioner Bell?

Sr. J. Cardenas: I wish to ask one or two questions in connection with the paper just read by Mr. Bell. I would like to know just what is the scope of sport fishing, that is, what is the dividing line between sport and commercial fishing, a question of interest to both scientists and those with economic and sporting purposes only. The point is this. It is quite possible that a man engaged in fishing for sport may catch such a quantity of fish as may be regarded to be excessive, and to the contrary it is possible the commercial fisherman may carry on commercial fishing for sport. One case in point is in the United States where apparently there is a kind of boat called a "Jig," up to five tons capacity, which has a mast that can be spread so that one-half of it can be used perpendicularly for the sail and the other half be stuck out horizontally as an arm to which hooks and sinkers may be attached; and these "Jigs" are supposed to be sporting boats only and not regular fishing boats. I wish to know whether there is a regulation in the United States which controls this kind of fishing. Either the "Jig" fishermen are looked upon as sportsmen or as commercial fishermen. Usually the sport fisherman is a man concerned with bringing home a trophy, and he always has a certain amount of satisfaction, but at the same time there is a possibility that a man, under the guise of being a sportsman, may catch a great amount of fish and therefore trespass on the grounds of the commercial fisherman. On the other hand, there is a possibility that persons engaged in fishing for a livelihood may do so under the guise of being sportsmen, and I would like to know just what the situation is in this regard in the United States.

Mr. Bell: I suppose there is a conflicting interest. I am not familiar with the same. On the Pacific Coast, up the California Coast of course, the State patrols the waters. I believe Mr. Davis could answer that better than I. There is no federal regulation against the use of "Jigs."

Mr. Herbert Davis: With respect to the "Jig" boat, which probably is the boat which we call a troll boat, that is classed as strictly a commercial boat, it is used in California almost exclusively for salmon fishing. It is true that the

total catch of all sportsmen in California, of any of our species that are also commercial species, equals the commercial catch and in some instances exceeds it. There is very little danger of sport fishermen fishing commercially under the guise of sportsmen and also very little danger of the commercial fisherman actually carrying on his operations under a similar guise, because of the California laws relating to commercial fishermen which would prohibit them from selling their catch unless they were licensed as commercial fishermen. Under the sport fishing license no part of the catch may be sold and it is easy to enforce that law.

Sr. Rodriquez Méndez: You clarified the point in connection with the question asked by Sr. Cardenas. The Department of Game and Fisheries of Mexico has always considered "Jig" fishing as a commercial proposition and this point should be made clear because there is a probability that some people may have confused "Jig" fishing with fishing for sport. Besides this the law of Mexico prevents people who are sport fishing from disposing of their catch by sale and is similar to that law in the United States.

Sr. Cardenas: With regard to the point brought up by Sr. Méndez, I would like to make the situation entirely clear. I did not intend in any way to refer to the Mexican law, as I am thoroughly familiar with it, but I did want to raise a point in connection with the paper read by Mr. Bell in regard to the matter under consideration so that there should be no confusion relative to the scope of sport fishing. Since Mr. Bell referred to both the scientific and commercial interests in fishing and very little to the sporting interests, I wished to hear his opinion in reference to fishing from the sport standpoint, and the American regulation of it, without any reference to the application of the Mexican law. What I wished to know was if the idea had occurred to him that a group of sport fishermen might take such a boat and go out fishing and use it for commercial purposes, and also if a commercial fisherman of many years, might also convert it into use for sport fishing.

THE FOOD OF THE LAKE TROUT (*CRISTIVOMER NAMAYCUSH NAMAYCUSH*) AND OF THE LAWYER (*LOTA MACULOSA*) OF LAKE MICHIGAN[1]

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ABSTRACT

This paper reports on a qualitative and quantitative analysis of the contents of 4,979 lake trout stomachs (593 examined in 1930 and 1,253 collected in 1931 from southern Lake Michigan, 1,446 from northern Lake Michigan and 1,687 from Green Bay in 1932), and of a total of 1,528 lawyer stomachs (172 examined in 1930 and 734 collected in 1931 from southern Lake Michigan, 612 from northern Lake Michigan and 10 from Green Bay in 1932). The food of the trout consisted of 98 per cent by volume of fish of which Cottidae and Coregonidae were the principal constituents. Cottidae were dominant in southern Lake Michigan (72 per cent by volume), Coregonidae in northern Lake Michigan (51 per cent) but the lake shiner, *Notropis atherinoides*, was most important in Green Bay in the spring of the year (64 per cent). The lawyer food consisted of 74 per cent by volume of fish and 26 per cent invertebrates. Dominant items were Cottidae (76 per cent by volume) in southern Lake Michigan, Coregonidae (51 per cent) and *Pontoporeia* (37 per cent) in northern Lake Michigan, and *Percopsis* (34 per cent) and *Mysis* (26 per cent) in Green Bay. Data are also presented on the frequency of occurrence (number of stomachs) of the food items and its variation with the sizes of the trout and lawyers, depths of water, seasons, and localities; on the number of individual fish of each species destroyed by the trout and lawyers; and on the calculated volume of the food fishes preceding digestion. The lake trout and lawyer are competitors for the same food, are both predators of the commercially important Coregonidae, and the lawyer through its consumption of invertebrates is a food competitor of the Coregonidae.

INTRODUCTION

The data and materials on which this paper is based were obtained during the extensive cooperative investigation of the chub (*Leucichthys* spp.) fisheries of Lake Michigan conducted under the direction of the U. S. Bureau of Fisheries in 1930, 1931, and 1932. The principal objective of this investigation was to determine the destructiveness of chub gill nets of various sizes of mesh to immature lake trout, *Cristivomer namaycush namaycush* (Walbaum). The incentive for this work lay in the differences in the legal codes of the States of Michigan, Wisconsin, Illinois, and Indiana, that regulated the size of the mesh in these nets, and in the desire of these states to obtain information which would enable them to enact uniform laws.

In addition to the data on gill-net selectivity and on the feeding habits of certain Lake Michigan fishes, materials were also collected to show the nature and abundance of the food available in the lake. Quantitative studies of the bottom fauna (Eggleton, 1936 and 1937)

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and a qualitative study of the phytoplankton (Ahlstrom, 1936) have already been published. Preserved samples for a similar study of the zooplankton are available.

In 1930 a rough qualitative examination of a number of lake trout and lawyer, *Lota maculosa* (Le Sueur), stomachs was made in the field. In 1931 and 1932 a much larger number of stomachs of these fish was collected and preserved in order to determine more exactly to what extent these species are competitors for the same food and are predatory on the chub or whitefish population (Coregonidae). This paper presents the results of the quantitative and qualitative examination of the stomach contents and represents the first detailed study of the feeding habits of lake trout and lawyers (also called ling, burbot, and eel-pout) in Lake Michigan.

Of the large number of published reports or statements on the food of the lake trout and of the lawyer only three refer definitely to Lake Michigan specimens. (No doubt the ten lawyers studied by Forbes (1888) were also taken from Lake Michigan although no locality record is given.) Milner (1874) and Bean (1903) made some general statements concerning the food of the Lake Michigan lake trout, and Pearse (1921) examined the stomachs of ten lake trout and ten lawyers from the Lake Michigan waters off Door County, Wisconsin. Milner found the food to consist principally of the bloater, *Leucichthys hoyi,* with an occasional specimen of some other species of fish. He stresses the point that no whitefish were taken. Bean wrote with respect to the trout, "In Lake Michigan it feeds largely on the cisco and other small whitefishes." Pearse computed the following percentages of various items in the food by volume: Lake trout—Cottidae 21, *L. hoyi* 23, other fish 46, grasshoppers 10. Lawyer—*L. hoyi* 40, other fish 43.8, *Mysis* 8.9, amphipods 3.3, Sphaeriidae 0.6, bottom mud 2.8. Because of the restricted locality of capture and the small number of specimens employed Pearse's lists of food items do not include all of the forms utilized by the trout and lawyers throughout the lake.

Clemens *et al.* (1923 and 1924) analyzed the stomach contents of 105 lake trout and 242 lawyers from Lake Nipigon. The bulk of the food of the trout consisted of ciscoes (*Leucichthys* spp.) and that of the lawyer of *Mysis* for fish 12 to 22 inches long and of ciscoes for larger individuals. Dymond (1928) studied the food of 128 lake trout and 64 lawyers from Lake Ontario. He found that in early summer the dominant food of the trout was the alewife, *Pomolobus pseudoharengus* (Wilson), a species which does not occur in Lake Michigan, and in late summer the ciscoes, *Leucichthys* spp. The other food forms included the deep-water sculpin, miller's thumb, nine-spined stickleback, and menominee whitefish. Alewives, crayfish, and cottids comprised the staple food items of the lawyer. Eaton (1928), who examined the stomach contents of 137 lake trout from the Finger Lakes of New York, found that in three of the

lakes this species subsisted almost exclusively on alewives and in the other three lakes largely on ciscoes and sculpins. The Annual Report of the Ontario Game and Fisheries Department (1933, p. 12) refers to an examination of 100 lawyer stomachs taken in January from Rideau and Otter lakes. Only fish were reported taken from the stomachs. It is of interest to note that 10 per cent of the lawyers had preyed on the smallmouth black bass, *Micropterus dolomieu* Lacépède. Fry and Kennedy (1937) analyzed the stomach contents of 167 lake trout taken by anglers from Lake Opeongo, Ontario, and found that fish, principally whitefish and yellow perch, comprised by far the most important item in the diet.

Twenty-six additional papers which made reference to the food of either the lake trout or lawyer or of both in North American waters have been examined. The statements in these papers either express a general conclusion without the presentation of detailed data, often based principally on the work of Milner (1874), or have been based on an examination of from one to twenty-eight specimens from a lake or stream and hence are not sufficiently important to merit attention here.

Materials and Methods

The trout and lawyers from which stomachs were removed were taken in gill nets with stretched meshes of the following sizes: 2⅜, 2½, 2⅝, 2¾, and 3 inches. Five hundred and ninety-three lake trout and 172 lawyer stomachs were examined in the field in 1930, and 4,386 lake trout and 1,356 lawyer stomachs were examined or preserved in 1931 and 1932—a grand total of 4,979 lake trout and 1,528 lawyer stomachs. The 1931 samples were taken from that region of the lake to the southward of an imaginary line drawn from Frankfort, Michigan, to Algoma, Wisconsin, and the 1932 materials were collected in that area of the lake to the northward of this line and in Green Bay. All of the 1930 collections were taken south of the line with the exception of two lawyer stomachs (one void) and twenty-four trout stomachs (fifteen void) which were taken off the southeastern shore of South Fox Island on June 26 and July 7. The samples from southern Lake Michigan were taken out of the ports of Grand Haven, Ludington, and Frankfort, Michigan, on the east shore and out of Kewaunee, Two Rivers, Sheboygan, Port Washington, and Racine, Wisconsin, and Waukegan, Illinois, on the west shore. The northern Lake Michigan collections were obtained in the vicinities of South Manitou Island, the Fox Islands, Beaver Island, Charlevoix, and Manistique, Michigan. The Green Bay material was taken from the deeper central area of the bay. Other details concerning these collections are given in tabular form on the following page.

At the time of removal from the fish, each stomach was wrapped separately in a small piece of muslin to which a serially numbered tin tag was fastened. The tag number was recorded in the field

notes together with the locality, date, length, weight, and sex of the fish, size of gill-net mesh used, and the depth of water. Stomachs were preserved in a 10 per cent formalin solution and upon arrival at the laboratory were washed in running water and transferred to 70 per cent alcohol. The empty stomachs were not preserved but were recorded as void in the notes.

Year	Region of lake	Species	Number of specimens examined	Period of collection	Depth of water in fathoms
1930	Southern	trout	593	June 26-August 14; November 8.	25-85
		lawyer	172	July 3-August 12; November 8.	25-80
1931	Southern	trout	1,253	June 1-August 19; October 9-November 13	27-97
		lawyer	734	July 3-November 14	23-101
1932	Northern	trout	1,446	June 10-September 7	17-68
		lawyer	612	June 10-September 7	23-93
1932	Green Bay	trout	1,687	April 28-May 28	14-19
		lawyer	10	April 29 and May 25	14-18

Laboratory analyses of the stomach contents were carried out by the customary liquid displacement method. The contents were sorted by species or by a larger taxonomic group, the number of individuals of each kind was recorded when possible, and the excess liquid on the preserved specimens was absorbed with pieces of filter paper. The total liquid displacement of each kind of food in a graduated cylinder partially filled with alcohol was then recorded in milliliters. The quantity of food to be measured determined the size of the graduated cylinder used. The analytical data were written on three by five-inch cards, a separate card being used for each stomach. This procedure facilitated summarization of the data.

The assistance of Dr. Carl L. Hubbs in identifying some of the fishes is gratefully acknowledged.

Length Frequency Distribution, Sex Ratio, and Sexual Maturity of the Lake Trout and Lawyers

Numerical and percentage length frequency distributions of the lake trout whose stomach contents were analyzed are presented in Table 1 arranged by one-inch intervals of total length. Corresponding intervals of standard length in millimeters are also indicated. Collections from the three general regions of the lake covered approximately the same length range, although the Green Bay specimens averaged the smallest and the northern Lake Michigan specimens the largest in length. The small differences in average size were unquestionably due to gear selection. All five sizes of mesh (2⅜, 2½, 2⅝, 2¾, and 3 inches) were fished in southern Lake Michigan, the four smallest sizes in Green Bay, and the three middle sizes (2½, 2⅝, and 2¾ inches) in northern Lake Michigan.

Fifty-three per cent of the trout taken in 1931 and 1932 were males and 47 per cent were females, the corresponding percentages for the two years being almost identical. Ninety-nine and six-tenths per cent of the males and 99.3 per cent of the females were sexually immature, the various corresponding percentages for the two years again being almost identical. The food studies of the trout, therefore, represent only the immature stock in the population.

TABLE 1. NUMERICAL AND PERCENTAGE LENGTH FREQUENCY DISTRIBUTION OF THE LAKE MICHIGAN LAKE TROUT OF WHICH STOMACHS WERE EXAMINED. THE AVERAGE LENGTH OF THE FISH OF EACH REGION IS SHOWN IN THE LAST TWO ROWS

Total length (inches)	Standard length[1] (millimeters)	Southern Lake Michigan 1931		Northern Lake Michigan 1932		Green Bay 1932		Total	
		Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Under 9	Under 192	1	0.1	----	----	3	0.2	4	0.1
9 to 10	192 to 213	1	0.1	1	0.1	6	0.4	8	0.2
10 to 11	213 to 234	22	1.8	4	0.3	40	2.4	66	1.5
11 to 12	234 to 256	175	14.0	36	2.5	320	19.0	531	12.1
12 to 13	256 to 277	296	23.8	235	16.2	512	30.3	1,043	23.8
13 to 14	277 to 298	303	24.3	460	31.8	522	30.9	1,285	29.3
14 to 15	298 to 320	205	16.4	358	24.8	219	13.0	782	17.8
15 to 16	320 to 341	129	10.4	178	12.3	35	2.1	342	7.8
16 to 17	341 to 362	59	4.7	89	6.2	19	1.1	167	3.8
17 to 18	362 to 384	32	2.6	57	3.9	8	0.5	97	2.2
18 to 19	384 to 405	5	0.4	17	1.2	3	0.2	25	0.6
19 to 20	405 to 426	8	0.6	7	0.5	----	----	15	0.3
20 to 21	426 to 448	----	----	2	0.1	----	----	2	[3]----
21 to 22	448 to 469	2	0.2	1	0.1	----	----	3	0.1
22 and over	469 and over	8	0.6	1	0.1	----	----	9	0.2
Total number		[2]1,246		1,446		1,687		[2]4,379	
Average length (millimeters)		291		303		276		289	
Average length (inches)		13.6		14.2		12.9		13.6	

[1]The total length is 1.192 times the standard length and the standard length is 0.839 times the total length.
[2]Does not include seven specimens which were so mutilated that they could not be measured.
[3]Less than 0.05 per cent.

The numerical and percentage length frequency distributions of the lawyers (Table 2) also are arranged by one-inch intervals of total length and the equivalent standard lengths stated in millimeters. As in the trout the difference in the average length of the lawyers of the two Lake Michigan collections may be explained on the basis of gear selection. These two collections, however, covered approximately the same size range. The fact that only ten lawyers were taken in Green Bay suggests that this species does not inhabit

in any large numbers the comparatively shallow waters of Green Bay during April and May.

In 1931 some 61 per cent of the lawyers were males, 39 per cent were females, but in 1932 the sex ratio was 50-50. If the data of both years are combined the percentages are 56 for the males, 44 for the females. Of the 1931 males and females 97 per cent of each sex were sexually mature, but in 1932 only 82 per cent of the males and 74 per cent of the females were mature. The food studies of the lawyer, therefore, represent largely the adult population, although the majority of the specimens were undoubtedly young individuals.

Number and Percentage of Void Stomachs

The length of time the fish were in the nets after capture (when further feeding was impossible but digestion could continue) was an important factor in the degree of digestion of the stomach contents and the percentages of void stomachs. In Lake Michigan prop-

TABLE 2. NUMERICAL AND PERCENTAGE LENGTH FREQUENCY DISTRIBUTION OF THE LAKE MICHIGAN LAWYERS OF WHICH STOMACHS WERE EXAMINED. THE AVERAGE LENGTH OF THE FISH OF EACH REGION IS SHOWN IN THE LAST TWO ROWS

Total length (inches)	Standard length[1] (millimeters)	Southern Lake Michigan 1931		Northern Lake Michigan 1932		Green Bay 1932		Total	
		Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Under 11	Under 261	1	0.1	----	----	----	----	1	0.1
11 to 12	261 to 285	11	1.5	5	0.8	----	----	16	1.2
12 to 13	285 to 308	37	5.1	26	4.2	----	----	63	4.6
13 to 14	308 to 332	118	16.1	87	14.2	1	10.0	206	15.2
14 to 15	332 to 356	179	24.5	129	21.1	----	----	308	22.7
15 to 16	356 to 380	167	22.8	94	15.4	----	----	261	19.3
16 to 17	380 to 403	131	17.9	38	6.2	----	----	169	12.5
17 to 18	403 to 427	55	7.5	21	3.4	----	----	76	5.6
18 to 19	427 to 451	13	1.8	33	5.4	1	10.0	47	3.5
19 to 20	451 to 475	5	0.7	44	7.2	2	20.0	51	3.8
20 to 21	475 to 498	9	1.2	40	6.5	1	10.0	50	3.7
21 to 22	498 to 522	4	0.5	41	6.7	3	30.0	48	3.5
22 to 23	522 to 546	1	0.1	22	3.6	1	10.0	24	1.8
23 to 24	546 to 569	1	0.1	15	2.4	----	----	16	1.2
24 to 25	569 to 593	----	----	9	1.5	----	----	9	0.7
25 to 26	593 to 616	----	----	5	0.8	----	----	5	0.4
26 and over	616 and over	----	----	3	0.5	1	10.0	4	0.3
Total number		[2]732		612		10		[2]1,354	
Average length (millimeters)		361		400		496		380	
Average length (inches)		15.2		16.9		20.9		16.0	

[1]The total length is 1.071 times the standard length and the standard length is 0.934 times the total length.

[2]Does not include two specimens which were so mutilated that they could not be measured.

er, nets were usually in the water from five to ten days before being lifted but in Green Bay this time interval was only two to five days. A greater percentage of void stomachs should therefore be expected in the Lake Michigan samples than in those from Green Bay. Of the 4,979 lake trout stomachs examined, 2,205 or 44.3 per cent were empty. The percentages of void stomachs were approximately equal in the southern (48.6) and northern (50.0) Lake Michigan specimens but a smaller percentage of the stomachs was empty in the trout captured in Green Bay (34.6).

Of the 1,528 lawyer stomachs examined 254 or 16.6 per cent were void. In the southern Lake Michigan samples 14.7 per cent and in the northern Lake Michigan specimens 19.3 per cent contained no food. The number of lawyers taken in Green Bay is too small to afford reliable information. That the percentages of void lawyer stomachs were smaller than the corresponding percentages of the lake trout may be explained by the facts that some of the lawyers were captured because of their attempts to devour the fish already gilled in the nets and that others were "mouthed" instead of thrusting the head through the meshes of the net. In either event the mouth was plugged or held closed, respiration was impeded, and death ensued more rapidly than in those fish that had inserted the entire head through the meshes and continued to respire.

Frequency of Occurrence of Food Items and Its Variation With Sizes of Trout and Lawyers, Depths of Water, Seasons, and Localities

The relative importance of the various organisms in the diet of lake trout and lawyers may be shown by the per cent of the total number of stomachs in which they were found. In examining the percentages it is necessary to remember that the same stomach frequently contained more than one item of food. Also, the various items in the stomach were not all digested to a like extent; some could be identified to species, some to genus only, and still others were so badly fragmented or completely digested that only the family could be designated. With respect to *Mysis* and *Pontoporeia* any unidentifiable mass of these forms was divided on the basis of the proportionate representation of the recognizable individuals.

Variation With the Sizes of Lake Trout and Lawyers. In order to determine whether there were any marked changes in feeding habits which could be correlated with the size of the trout or lawyer, tables were drawn up for each of the larger collections to show for the fish of each one-inch length frequency interval the percentage of the individuals that had consumed the principal types of food. In order to conserve space the tables are not reproduced here. An examination of the data showed that the lake trout captured in the region of Racine in 1931 had eaten fish exclusively after having reached a

total length of 15 inches. The trout less than 15 inches long had consumed largely Cottidae and invertebrates; those larger than 15 inches had eaten Cottidae and Coregonidae. At Charlevoix in 1932 no stomachs of trout over 17 inches total length contained invertebrates. The percentage of each size group of the lake trout over 15 inches long that had fed on Coregonidae averaged about three times that of the trout under this size and the percentage of each size group of the trout under 13 inches that had subsisted on Cottidae averaged about twice that of the trout larger than 13 inches. At Manistique in 1932 no trout larger than 18 inches had consumed invertebrates. The nine-spined stickleback was found in a greater percentage of the stomachs than was any other item and occurred most frequently in the food of trout smaller than 16 inches. Cottidae were not found in stomachs of fish over 18 inches in length and the percentage of occurrence of Coregonidae in the food of trout over 17 inches averaged nearly seven times that in the diet of the smaller individuals. Only 3 of the 1,103 Green Bay lake trout employed were larger than 18 inches in length and among these 1,100 fish there were no significant differences in feeding habits with size.

It may be seen, then, that in Lake Michigan as a whole, lake trout larger than 18 inches in length seldom consumed invertebrates. Coregonidae increased in relative importance as a food item in the diet of lake trout over 15 inches in length and Cottidae, on the whole, were relatively more important to the smaller than to the larger fish. Forage fishes, such as *Notropis* and *Pungitius,* were seldom eaten by lake trout larger than 18 inches in length.

The lawyers of virtually all size groups (11-21 inches) captured in the vicinity of Racine in 1931 had taken invertebrates, although the percentage of fish which had eaten these forms tended to decrease with each higher size group. No lawyers under 14 inches in length had eaten Coregonidae and only 2.7 per cent of those larger than this size had fed on this group. The percentages of stomachs which contained Cottidae tended to increase with an increase in the length of the lawyers. At Manistique in 1932 the percentages of stomachs which contained invertebrates decreased materially after the lawyers had reached a length of 18 inches, and no invertebrates occurred in the stomachs of fish 24 inches or more in length. Coregonidae were not found in the stomachs of any lawyers smaller than 15 inches and there was a tendency for the percentage representation to increase with an increase in the length of the fish. Cottidae were recognized only in stomachs of individuals which measured 13 to 21 inches in length and appeared to be as important a food item in the smaller as in the larger individuals within this size range.

Thus it is seen that the Lake Michigan lawyers of virtually all size groups up to 24 inches in length had subsisted in part on invertebrates, although the smaller fish had fed more extensively on these

food organisms than had the larger individuals. No lawyers under 14 inches in length had eaten Coregonidae and there was a tendency for the percentage of lawyers which had taken these forms to increase with each higher size group. Cottidae were consumed by lawyers of all sizes (11-24 inches) with some tendency for the percentage of each size group to increase with an increase in the length of the fish.

Variation With Depths of Water. No accurate detailed data on the relationship of the feeding habits of lake trout and lawyers to depths of water are available, because the experimental nets in which the fish were caught were so set that each gang covered a wide and varying range of depth. However, simultaneous lifts of nets from water shallower than and from water deeper than 45 fathoms were made frequently. Therefore, feeding habits may be compared of fish which inhabited these two general depth ranges. Lifts made off Frankfort in 1931 and off Charlevoix in 1932 covered such wide bathymetric ranges that they could not be separated into shallow and deep-water lifts on the basis of a dividing line of 45 fathoms. Neither could the Green Bay data be used for this comparison because they were obtained from water much shallower than the least depth fished in Lake Michigan proper. Although tables have been drawn up for study, they are not included in this paper.

No definite correlation was found between the percentages of stomachs that contained invertebrates and the depth of water from which the trout were taken. The percentages of stomachs which contained Cottidae were invariably higher for trout taken in the deeper water than for those captured in the shallower water. At all six localities studied (Racine, Sheboygan, Two Rivers, Manistique, Leland, Ludington), except Leland (only five stomachs taken from deep water) and Racine (only 1.3 per cent of 158 deep-water trout and no shallow-water trout contained *Cottus*), the genus *Cottus* was more widely used as food by the shallow-water trout than by the deep-water fish, and everywhere but at Leland the genus *Triglopsis* was more widely consumed by the trout which came from deep water than by those taken from shallow water. Except at Manistique, where the percentages were approximately equal for both depth ranges of water, the Coregonidae occurred more frequently in the stomachs of trout caught in shallow water than in those taken from trout in deep water. The nine-spined stickleback, not found in the trout stomachs taken from southern Lake Michigan, was apparently an important food item only for the trout living in less than 50 fathoms of water in northern Lake Michigan.

There appeared to be no definitely fixed correlation between the frequency of occurrence of invertebrates in lawyer stomachs and the depth of water in which the fish were captured, although on the whole (five out of eight localities) the lawyers caught in shallow water had fed more extensively on invertebrates than had those

captured in deep water. The percentages of stomachs which contained Cottidae showed no definite correlation with depth of water but members of the genus *Cottus* were found more frequently in the stomachs of lawyers taken from shallow waters than in those caught in the deep water, and *Triglopsis* was found in a much higher percentage of the stomachs of individuals from deep water than of those from shallow water, except at Leland and the Manitou Islands. Coregonidae were better represented in lawyer stomachs from shallow-water lifts than from the deep-water lifts made off the ports of Grand Haven, Leland, Two Rivers, and Racine, but the reverse was true in northern Lake Michigan in the region of the Manitou Islands and off Manistique. No Coregonidae were eaten by lawyers taken in the vicinity of Ludington and of Kewaunee.

The above data indicate that the relationship of the feeding habits of both the trout and lawyer to depth of water is dependent to a large extent on the bathymetric distribution of the food organisms involved. *Cottus* is found most abundantly in the shallower waters, *Triglopsis* in the deeper waters studied (Deason, MS.). So also the smaller individuals of the Coregonidae, upon which both the trout and lawyers fed, occur most abundantly at the shallower depths considered.

Variation With Seasons. In order to determine whether there were any seasonal variations in the feeding habits of lake trout, four of the largest collections were studied in detail, keeping the lifts from shallow water separate from those from deep water. The total number of stomachs which contained food and the number and percentage of the total in which the principal items were found were recorded according to dates for the Racine, Charlevoix, Manistique, and Green Bay areas. The Racine data, which embodied five collections made during June, July, October, and November, 1931, suggested that the trout had fed less extensively on Cottidae and more extensively on Coregonidae in June than in the other months indicated, although the variations in the percentages may have been due in part to differences in depth of water from which the trout were taken, rather than in the season. At Charlevoix (eight collections) the lake trout had fed less on *Cottus* spp. and more on *Coregonidae* during the period, July 18-August 4, 1932, than on August 13, 15, and 17, 1932. Variations in the percentage occurrence of other food items were probably random. The eight collections made out of Manistique during the period, June 10 to September 7, 1932, showed no consistent variations in the feeding habits of the lake trout, except those that could be correlated with the depth of water from which they were taken. No consistent variations with the season were found in the Green Bay trout material (thirteen samples) collected during the period, April 28-May 28, 1932, except that after May 12 *Cottus* increased in importance in and *Notropis atherinoides* disappeared from the diet of these trout. These changes cannot be

attributed to variations in depth of water from which the trout were taken, but may be correlated with the concentration of *Notropis atherinoides* incidental to the spawning run and the movement inshore.

A search for seasonal variations in the feeding habits of the lawyer was made through a detailed analysis of the collections from the vicinity of Racine (twelve samples) and of Manistique (eleven samples) which covered a longer time interval than material from any of the other ports. At Racine during the period, July 10 to November 11, 1931, the shallow-water Cottidae increased in importance in September, while the deep-water Cottidae showed a progressive increase in frequency of occurrence in the stomachs as the season advanced. No seasonal variation was found in the frequency of occurrence of the invertebrates and too few Coregonidae were consumed to give any reliable data on these species. At Manistique there seemed to have been a general decrease in the frequency of occurrence of fish in the lawyer diet as the season advanced from June 10 to July 11, 1932, with a sharp increase on September 7, 1932. Because many of the food fishes could not be identified, it is impossible to give further details except to state that no seasonal variations appeared in the data of the Coregonidae and invertebrates.

The above data suggest that the Cottidae assume a greater and the Coregonidae a lesser importance in the diet of the lake trout and the lawyer as the season advances from early summer to fall. It is possible that had stomach collections been made during the winter and early spring, other and more significant seasonal differences would have been detected.

Variation With Localities. Since the feeding habits of the trout and lawyers studied were found to vary with the lengths of the individuals, with the depth of water from which they were taken, and with the season, any variation found with localities may be due to differences in these factors. However, in our trout and lawyer data the size range remained approximately constant for the species at all localities within a region so that only two of the above three factors could be involved. An examination of our data, however, revealed no significantly consistent variations in the food composition of either the trout or lawyer with the localities of southern Lake Michigan. In 1931 the Cottidae comprised the dominant food item of the lawyer at all localities except Waukegan, Illinois, as determined from the percentages of the total number of stomachs that contained this form. The percentages are as follows: Grand Haven 76, Ludington 78, Frankfort 69, Kewaunee 88, Two Rivers 59, Sheboygan 78, Port Washington 100, Racine 67, and Waukegan 45. *Mysis* ranked second in occurrence at all localities except at Waukegan where it ranked first. Similarly, most of the trout taken at these localities subsisted on Cottidae, the Coregonidae ranking second in occurrence except at Waukegan where *Mysis* replaced them. In northern Lake Michigan the results were likewise fairly consistent. *Pontoporeia* occurred

in the majority of the lawyer stomachs at each locality. The percentages of occurrence are: South Manitou Island 50, Leland 84, Charlevoix 71, and Manistique 81. At South Manitou and Leland the cottids ranked second, Coregonidae third in frequency of occurrence, but at Charlevoix and Manistique the coregonids ranked second and Cottidae third. In the lake trout of northern Lake Michigan the cottids occurred most frequently in the stomachs of specimens taken at South Manitou Island, Beaver Island, and Manistique but ranked second at Leland and Charlevoix, where coregonids ranked first. Coregonids ranked second in the first named localities.

It has already been pointed out that the observed differences in feeding habits may no doubt be correlated with the bathymetric distribution of the various species consumed. *Triglopsis* is a deep-water form, *Cottus* a shallow-water fish. *Mysis* seems to be dominant in the southern region, *Pontoporeia* in the northern area of the lake. However, since both the trout and lawyers taken within any one of the three general regions of the lake showed remarkably uniform feeding habits each may be treated as a homogeneous group within each region.

1930 Data. Since no stomachs of the lake trout and lawyers were preserved in 1930 and no volumetric studies were conducted in the field but only a record made of the taxonomic groups represented in the contents of each stomach and since more detailed data were collected in 1931 and 1932 than in 1930 it will suffice to present the 1930 data in summary form. In the following paragraphs are given the total number of stomachs examined, the per cent of empty stomachs, and the percentages of the total number of stomachs in which the various types of food were found.

Lake trout—593 stomachs; 43.8 per cent void; Cottidae in 25.5 per cent, Coregonidae in 8.3 per cent, *Pungitius pungitius* in 0.7 per cent, *Pontoporeia* and *Mysis* in 2.7 per cent, unidentifiable fish fragments in 22.3 per cent, fish eggs in 0.7 per cent, and debris in 1.2 per cent of the total number of stomachs.

Lawyers—172 stomachs; 16.3 per cent void; Cottidae in 38.4 per cent, Coregonidae in 2.9 per cent, *Pontoporeia* and *Mysis* in 41.8 per cent, unidentifiable fish fragments in 31.4 per cent, fish eggs in 1.7 per cent, and debris in 1.2 per cent of the total number of stomachs.

The data for 1930 agree fairly well with the corresponding data for 1931 shown in Tables 3 and 4. In both trout and lawyers the proportionately greater number of stomachs that contained Cottidae in 1931 is correlated with the proportionately larger number of stomachs that contained unidentified fish remains in 1930 which suggests that the important differences in the results of the two years may be attributed to the less detailed method of analysis employed in 1930 which led to the failure to recognize many fish remains as Cottidae.

1931 and 1932 Data. Tables 3 and 4 present the 1931 and 1932

data on the number of lake trout and lawyer stomachs in which the various food items occurred. The trout of all regions fed principally on fishes which were found in 91 to 95 per cent of the stomachs that contained food. Only 6.7 per cent of the trout consumed invertebrates, mainly *Mysis relicta.* In southern Lake Michigan 73.2 per cent of the stomachs contained Cottidae, predominantly *Triglopsis thompsonii.* Coregonidae ranked second but were found in only 10.2 per cent of the stomachs. In northern Lake Michigan

TABLE 3. FOOD OF THE LAKE MICHIGAN LAKE TROUT, 1931 AND 1932. TOTAL NUMBER OF STOMACHS EXAMINED, NUMBER AND PER CENT VOID AND CONTAINING FOOD, NUMBER OF STOMACHS AND THE PER CENT OF NUMBER OF STOMACHS CONTAINING FOOD IN WHICH THE VARIOUS ITEMS WERE FOUND

Item	Southern Lake Michigan 1931		Northern Lake Michigan 1932		Green Bay 1932		Total	
	Number of stomachs	Per cent of total number	Number of stomachs	Per cent of total number	Number of stomachs	Per cent of total number	Number of stomachs	Per cent of total number
Total number of stomachs	1,253	----	1,446	----	1,687	----	4,386	----
Number and per cent void	638	50.9	723	50.0	584	34.6	1,945	44.3
Number and per cent containing food	615	49.1	723	50.0	1,103	65.4	2,441	55.7
Fish:	584	95.0	688	95.2	1,007	91.3	2,279	93.4
Cottidae[1]	450	73.2	248	34.3	146	13.2	844	34.6
Cottus sp.[2]	13	2.1	8	1.1	146	13.2	167	6.8
Cottus ricei	3	0.5	31	4.3	60	5.4	94	3.8
Cottus cognatus	58	9.4	97	13.4	34	3.1	189	7.7
Triglopsis thompsonii	289	47.0	77	10.6	----	----	366	15.0
Coregonidae[1]	63	10.2	197	27.2	107	9.7	367	15.0
Leucichthys hoyi	8	1.3	46	6.4	18	1.6	72	2.9
Leucichthys artedi	----	----	2	0.3	3	0.3	5	0.2
Leucichthys reighardi	----	----	1	0.1	----	----	1	[3]----
Notropis atherinoides	----	----	5	0.7	569	51.6	574	23.5
Perca flavescens	----	----	----	----	5	0.4	5	0.2
Percina caprodes	----	----	2	0.3	----	----	2	0.1
Boleosoma nigrum nigrum	----	----	----	----	1	0.1	1	[3]----
Pungitius pungitius	----	----	131	18.1	3	0.3	134	5.5
Percopsis omiscomaycus	1	0.2	15	2.1	14	1.3	30	1.2
Osmerus mordax	----	----	----	----	8	0.7	8	0.3
Unidentified fish fragments	91	14.8	120	16.6	193	17.5	404	16.6
Fish eggs	7	1.1	2	0.3	2	0.2	11	0.4
Invertebrates:	22	3.6	48	7.0	83	7.5	153	6.7
Molluscs (*Musculium sp.*)	----	----	----	----	3	0.3	3	0.1
Mysis relicta	20	3.2	17	2.4	61	5.5	98	4.0
Pontoporeia hoyi	1	0.2	5	0.7	3	0.3	9	0.4
Grasshoppers	1	0.2	13	1.8	----	----	14	0.6
Dragonflies	----	----	1	0.1	----	----	1	[3]----
Beetles	----	----	1	0.1	----	----	1	[3]----
Midge larvae	----	----	----	----	1	[3]----	1	[3]----
Carpenter ants	----	----	12	1.6	16	1.4	27	1.1
Detritus	15	2.4	18	2.5	20	1.8	53	2.2

[1]Includes all individuals of this family.
[2]Material not identifiable to species.
[3]Less than 0.05 per cent.

TABLE 4. FOOD OF THE LAKE MICHIGAN LAWYERS, 1931 AND 1932. TOTAL NUMBER OF STOMACHS EXAMINED, NUMBER AND PER CENT VOID AND CONTAINING FOOD, NUMBER OF STOMACHS AND THE PER CENT OF NUMBER OF STOMACHS CONTAINING FOOD IN WHICH THE VARIOUS ITEMS WERE FOUND

Item	Southern Lake Michigan 1931		Northern Lake Michigan 1932		Green Bay 1932		Total	
	Number of stomachs	Per cent of total number	Number of stomachs	Per cent of total number	Number of stomachs	Per cent of total number	Number of stomachs	Per cent of total number
Total number of stomachs	734	—	612	—	10	—	1,356	—
Number and per cent void	105	14.3	118	19.3	3	30.0	226	16.7
Number and per cent containing food	629	85.7	494	80.7	7	70.0	1,130	83.3
Fish:	536	85.2	176	35.6	6	85.7	718	63.5
Cottidae[1]	425	67.6	34	6.9	2	28.6	461	40.8
Cottus sp.[2]	15	2.4	—	—	—	—	15	1.3
Cottus ricei	72	11.4	1	0.2	2	28.6	75	6.6
Cottus cognatus	10	1.6	8	1.6	—	—	18	1.6
Triglopsis thompsonii	270	42.9	24	4.8	—	—	294	26.0
Coregonidae[1]	24	3.8	85	17.2	3	42.8	112	9.9
Leucichthys hoyi	—	—	11	2.2	—	—	11	1.0
Leucichthys artedi	—	—	1	0.2	—	—	1	0.1
Leucichthys alpenae	—	—	2	0.4	—	—	2	0.2
Perca flavescens	1	0.2	—	—	—	—	1	0.1
Pungitius pungitius	—	—	5	1.0	—	—	5	0.4
Percopsis omiscomaycus	—	—	—	—	1	14.3	1	0.1
Osmerus mordax	—	—	—	—	1	14.3	1	0.1
Unidentified fish fragments	75	11.9	35	7.1	—	—	110	9.7
Fish eggs	22	3.5	29	5.9	—	—	51	4.5
Invertebrates:	281	44.6	385	77.9	4	57.1	670	59.3
Crayfish	3	0.5	3	0.6	—	—	6	0.5
Mysis relicta	251	39.9	127	25.7	4	57.1	382	33.8
Pontoporeia hoyi	58	9.2	296	59.9	1	14.3	355	31.4
Beetles	—	—	2	0.4	—	—	2	0.2
Detritus	50	7.9	14	2.8	—	—	64	5.7

[1]Includes all individuals of this family.
[2]Material not identifiable to species.

only 34.3 per cent of the trout had taken Cottidae, principally *Cottus*, 27.2 per cent had eaten Coregonidae, mostly the bloater, *Leucichthys hoyi*, and 18.1 per cent had consumed the nine-spined stickleback, *Pungitius pungitius*. The sticklebacks were nearly all taken off Manistique on June 10, 11, and 16 in 23-50 fathoms. In Green Bay 51.6 per cent of the stomachs which were collected in April and May contained the lake shiner, *Notropis atherinoides*, 13.2 per cent contained *Cottus*, and 9.7 per cent Coregonidae. We feel quite certain that all of the Coregonidae belonged to the genus, *Leucichthys*, since with one exception all of the Lake Michigan trout and lawyer specimens were taken beyond the usual bathymetric range of the whitefish and menominees from depths of 23 (138 feet) or more fathoms, and these species were seldom taken in our nets even in those set in the shallow water of Green Bay.

Eighty-five per cent of the lawyers of southern Lake Michigan and Green Bay (7 specimens) had fed on fishes but only 35.6 per cent of those taken in northern Lake Michigan had done so. A considerable percentage of the fish of all three regions had also taken invertebrates, principally *Mysis* in southern Lake Michigan and Green Bay, and predominantly *Pontoporeia* in northern Lake Michigan where this form occurred in 77.9 per cent of the stomachs or in 2.2 times the number of stomachs in which fish were found. The dominant fishes consumed in southern Lake Michigan were Cottidae, mostly *Triglopsis,* in northern Lake Michigan Coregonidae, principally *L. hoyi,* and Cottidae, mainly *Triglopsis,* and in Green Bay Coregonidae and *Cottus ricei.*

The smelt, *Osmerus mordax,* was not eaten by either the lake trout or the lawyers caught in Lake Michigan proper and was found in the stomachs of only eight lake trout and one lawyer from Green Bay. Van Oosten (1937) reported that the Great Lakes smelt were confined to waters shallower than 35 fathoms (210 feet) but were most abundant in water with depths of ten to twenty fathoms. Very

TABLE 5. FOOD OF THE LAKE MICHIGAN LAKE TROUT, 1931 AND 1932. TOTAL VOLUME OF ALL FOOD AND PER CENT OF THE TOTAL VOLUME REPRESENTED BY EACH ITEM IN THE FOOD

Item	Southern Lake Michigan 1931	Northern Lake Michigan 1932	Green Bay 1932	Total
Total volume of food (milliliters)[1]	3,779.5	3,341.6	4,520.2	11,641.3
Fish:	99.6	99.2	96.7	98.3
Cottidae[2]	72.4	31.3	7.9	35.5
Cottus sp.[3]	6.3	13.6	7.9	8.6
Cottus ricei	0.5	3.1	4.0	2.6
Cottus cognatus	5.2	10.1	1.8	5.3
Triglopsis thompsonii	59.3	14.3	—	23.3
Coregonidae[2]	24.4	50.7	16.2	28.8
Leucichthys hoyi	6.7	21.6	3.3	9.7
Leucichthys artedi	—	1.3	0.4	0.5
Leucichthys reighardi	—	0.2	—	0.1
Notropis atherinoides	—	0.4	64.4	25.1
Perca flavescens	—	—	0.2	0.1
Percina caprodes	—	0.3	—	0.1
Boleosoma nigrum nigrum	—	—	[4]—	[4]—
Pungitius pungitius	—	10.0	—	2.9
Percopsis omiscomaycus	[4]—	1.9	1.3	1.1
Osmerus mordax	—	—	2.5	1.0
Unidentified fish fragments	2.6	4.6	4.0	3.7
Fish eggs	0.2	[4]—	[4]—	[4]—
Invertebrates:	0.4	0.8	3.4	1.8
Mollusca	—	—	[4]—	[4]—
Mysis relicta	0.4	[4]—	1.2	0.6
Pontoporeia hoyi	[4]—	[4]—	1.5	0.6
Grasshoppers	[4]—	0.2	—	0.1
Dragonflies	—	[4]—	—	[4]—
Beetles	—	[4]—	—	[4]—
Midge larvae	—	—	[4]—	[4]—
Carpenter ants	—	0.4	0.7	0.4
Detritus[1]	0.3	0.3	0.4	0.3

[1]Detritus not included in total food.
[2]Includes all individuals of this family.
[3]Includes all individuals of this genus.
[4]Less than 0.05 per cent.

few of our nets were set at these shallow depths in the open lake and these were in localities from which the smelt had not yet been reported, at least in any numbers. Since 1933, however, smelt have been found in large numbers throughout many of the inshore areas of Lake Michigan and no doubt have become an important component of the food of the trout and perhaps of the lawyer. It is also of interest to note that the lawyer was not found in any of the lake trout stomachs, probably because of the small size of the trout, and no trout were observed in the stomachs of the lawyers.

Volume of Food in the Stomachs and Percentage Composition

The total volume of food in the stomachs and the percentage composition of the various food items are shown for the lake trout in Table 5 and for the lawyers in Table 6. Whereas the percentages based on the number of fish that subsisted on a particular item of food gave information on the extensiveness of the occurrence of this item in the food, the percentages based on the volumes of the various items give a better idea of the importance of each item from the point of view of nutrition. In general the conclusions based on the two kinds of percentages agree although the relative importance of the different food items shifted in certain instances. No shift oc-

TABLE 6. FOOD OF THE LAKE MICHIGAN LAWYERS, 1931 AND 1932. TOTAL VOLUME OF ALL FOOD AND PER CENT OF THE TOTAL VOLUME REPRESENTED BY EACH ITEM IN THE FOOD

Item	Southern Lake Michigan 1931	Northern Lake Michigan 1932	Green Bay 1932	Total
Total volume of food (milliliters)[1]	3,630.9	2,945.4	47.0	6,623.3
Fish:	88.1	57.4	66.8	74.3
Cottidae[2]	75.5	4.6	9.1	43.5
Cottus sp.[3]	12.2	1.0	9.1	7.2
Cottus ricei	9.6	[4]—	9.1	5.4
Cottus cognatus	1.5	0.9	—	1.2
Triglopsis thompsonii	58.9	3.3	—	33.8
Coregonidae[2]	9.6	51.1	15.3	28.1
Leucichthys hoyi	—	14.5	—	6.5
Leucichthys artedi	—	2.3	—	1.0
Leucichthys alpenae	—	9.4	—	4.2
Perca flavescens	[4]—	—	—	[4]—
Pungitius pungitius	—	0.1	—	[4]—
Percopsis omiscomaycus	—	—	33.6	0.2
Osmerus mordax	—	—	6.0	[4]—
Unidentified fish fragments	2.0	1.3	2.8	1.7
Fish eggs	1.0	0.3	—	0.7
Invertebrates:	11.9	42.6	33.2	25.7
Crayfish	0.1	0.1	—	0.1
Mysis relicta	8.7	5.2	26.4	7.3
Pontoporeia hoyi	3.0	37.2	6.8	18.2
Beetles	—	[4]—	—	[4]—
Detritus[1]	0.5	0.2	—	0.4

[1]Detritus not included in total food.
[2]Includes all individuals of this family.
[3]Includes all individuals of this genus.
[4]Less than 0.05 per cent.

curred in the food forms of the trout in southern Lake Michigan. In northern Lake Michigan the Coregonidae replaced *Cottus* in first place, the stickleback retaining its position in third place. In Green Bay the Coregonidae replaced *Cottus* in second place, the lake shiner retaining first place. In the lawyer greater changes took place. In the southern region Cottidae remained in first place but the Coregonidae which occurred in only 3.8 per cent of the stomachs assumed greater importance than did *Mysis* which were found in 39.9 per cent of the stomachs. In the northern area the Coregonidae moved from third place to first, *Pontoporeia* from first to second, and *Mysis* which occurred in 25.7 per cent of the stomachs shifted from second place to a position of relative insignificance (5 per cent by volume). In Green Bay the organisms shifted positions as follows: *Mysis*, Coregonidae, *Cottus* to *Percopsis*, *Mysis*, Coregonidae, *Cottus*.

Number of Individuals of Each Species of Fish Used as Food and Percentage Composition

From the point of view of predator relationship it is of interest to determine the numbers of individual fish of various kinds destroyed by the lake trout and lawyers (Tables 7 and 8). The percentages by number for the important forage fish of each of the three regions considered are: Lake trout—Cottidae 91.2, Coregonidae 8.7 in southern Lake Michigan; Cottidae 42.5, *Pungitius* 33.4, Coregonidae 21.9 in northern Lake Michigan; *Notropis atherinoides* 79.6, *Cottus* 11.4, Coregonidae 7.0 in Green Bay. Lawyer—Cottidae 96.9, Coregonidae 3.0 in southern Lake Michigan; Coregonidae 58.1, Cottidae 38.2 in northern Lake Michigan; *Cottus* 41.7, *Percopsis* 33.3, Coregonidae 16.7 in Green Bay. The number of Coregonidae, the only group that included species of commercial value, destroyed by the lake trout and lawyer was relatively small, except in northern Lake Michigan.

Comparison of the Number of Fish Consumed and Their Actual Calculated Volume

The total bulk of a food item is a better measure of its relative importance than the total number of individuals consumed. The volume actually measured, however, may fail to present an accurate estimate of the real food value of a species because in many instances the larger specimens were more completely digested than were the smaller individuals. Also, because of the differences in fat composition some fishes digest more rapidly than others. The soft Coregonidae undoubtedly disintegrate more rapidly than do the firmer, more bony sculpins and sticklebacks. In order to obtain some comparative data on the original and actual bulk of the various species of fish found in the stomachs, the volume of the specimens before digestion was calculated from volumetric measurements of preserved specimens of a size comparable to those eaten by the trout and law-

TABLE 7. MINIMUM TOTAL NUMBER OF FISH FOUND IN THE STOMACHS OF THE LAKE MICHIGAN LAKE TROUT, 1931 AND 1932, AND NUMERICAL AND PERCENTAGE COMPOSITION BY SPECIES

Item	Southern Lake Michigan 1931		Northern Lake Michigan 1932		Green Bay 1932		Total	
	Number of fish	Per cent of total number	Number of fish	Per cent of total number	Number of fish	Per cent of total number	Number of fish	Per cent of total number
Total number of fish in food	899	—	1,084	—	1,731	—	3,714	—
Cottidae[1]	820	91.2	461	42.5	197	11.4	1,478	39.8
Cottus sp.[2]	138	15.4	220	20.3	197	11.4	515	13.9
Cottus ricei	7	0.8	41	3.8	86	5.0	134	3.6
Cottus cognatus	116	12.9	168	15.5	44	2.5	328	8.8
Triglopsis thompsonii	512	57.0	158	14.6	—	—	670	18.0
Coregonidae[1]	78	8.7	237	21.9	121	7.0	436	11.7
Leucichthys hoyi	12	1.3	58	5.4	19	1.1	89	2.4
Leucichthys artedi	—	—	2	0.2	3	0.2	5	0.1
Leucichthys reighardi	—	—	1	0.1	—	—	1	[3]—
Notropis atherinoides	—	—	7	0.6	1,378	79.6	1,385	37.3
Perca flavescens	—	—	—	—	6	0.3	6	0.2
Percina caprodes	—	—	1	0.1	—	—	1	[3]—
Boleosoma nigrum nigrum	—	—	—	—	1	[3]—	1	[3]—
Pungitius pungitius	—	—	362	33.4	5	0.3	367	9.9
Percopsis omiscomaycus	1	0.1	16	1.5	14	0.8	31	0.8
Osmerus mordax	—	—	—	—	9	0.5	9	0.2

[1]Includes all individuals of this family.
[2]Includes all individuals of this genus.
[3]Less than 0.05 per cent.

TABLE 8. MINIMUM TOTAL NUMBER OF FISH FOUND IN THE STOMACHS OF THE LAKE MICHIGAN LAWYERS, 1931 AND 1932, AND NUMERICAL AND PERCENTAGE COMPOSITION BY SPECIES

Item	Southern Lake Michigan 1931		Northern Lake Michigan 1932		Green Bay 1932		Total	
	Number of fish	Per cent of total number	Number of fish	Per cent of total number	Number of fish	Per cent of total number	Number of fish	Per cent of total number
Total number of fish in food....	914	—	136	—	12	—	1,062	—
Cottidae[1]	886	96.9	52	38.2	5	41.7	943	88.8
Cottus sp.[2]	248	27.1	19	14.0	5	41.7	272	25.6
Cottus ricei	201	22.0	1	0.7	5	41.7	207	19.5
Cottus cognatus	20	2.2	18	13.2	—	—	38	3.6
Triglopsis thompsonii	524	57.3	25	18.4	—	—	549	51.7
Coregonidae[1]	27	3.0	79	58.1	2	16.7	108	10.2
Leucichthys hoyi	—	—	7	5.1	—	—	7	0.6
Leucichthys artedi	—	—	2	1.5	—	—	2	0.2
Leucichthys alpenae	—	—	2	1.5	—	—	2	0.2
Perca flavescens	1	0.1	—	—	—	—	1	0.1
Pungitius pungitius	—	—	5	3.7	—	—	5	0.5
Osmerus mordax	—	—	—	—	1	8.3	1	0.1
Percopsis omiscomaycus	—	—	—	—	4	33.3	4	0.4

[1]Includes all individuals of this family.
[2]Includes all individuals of this genus.

yers (Tables 9 and 10). Nine *Leucichthys hoyi* from Green Bay and fourteen from the vicinity of Washington Island averaged 160 millimeters standard length and had an average liquid displacement of 53.8 milliliters in alcohol. Twenty-four *Cottus ricei* and *Cottus cognatus* averaged 2.6 milliliters in volume and seventeen *Triglopsis thompsonii* averaged 6.7 milliliters, a grand average of 4.9 milliliters. This grand average was calculated on the basis of the proportionate representation of *Cottus* sp. (43.5 per cent) and *Triglopsis* (56.5 per cent) in the food of the trout. Forty-three *Notropis atherinoides* averaged 2.6 milliliters and forty-five *Pungitius pungitius* averaged 1.2 milliliters in volume. In Tables 9 and 10 the principal items of food have been assumed to constitute the entire stomach contents and the percentage representation of each item has been calculated from the total on the basis of 100 per cent. The data for all three regions of the lake have been combined.

The number of individuals, the actual volume of their bulk in the stomachs of the lake trout, and the theoretical volume of the same specimens before digestion, calculated from the average volume of comparable preserved individuals, are presented in Table 9. With

TABLE 9. COMPARISON OF ACTUAL VOLUME AND CALCULATED VOLUME OF THE PRINCIPAL FISHES EATEN BY THE LAKE MICHIGAN LAKE TROUT

Item	Number of specimens	Per cent of total number	Actual volume (milliliters)	Per cent of actual volume	Calculated volume (milliliters)	Per cent of calculated volume	Average volume per individual (milliliters)
Total	3,666	----	10,745.0	----	34,740.4	----	----
Cottidae spp.	1,478	40.3	4,138.4	38.5	7,242.2	20.8	4.9
Coregonidae spp.	436	11.9	3,348.4	31.2	23,456.8	67.5	53.8
Notropis atherinoides	1,385	37.8	2,925.3	27.2	3,601.0	10.4	2.6
Pungitius pungitius	367	10.0	332.9	3.1	440.4	1.3	1.2

TABLE 10. COMPARISON OF ACTUAL VOLUME AND CALCULATED VOLUME OF THE PRINCIPAL FISHES EATEN BY THE LAKE MICHIGAN LAWYERS

Item	Number of specimens	Per cent of total number	Actual volume (milliliters)	Per cent of actual volume	Calculated volume (milliliters)	Per cent of calculated volume	Average volume per individual (milliliters)
Total	1,051	----	4,739.4	----	10,808.3	----	----
Cottidae spp.	943	89.7	2,881.1	60.8	4,997.9	46.2	5.3
Coregonidae spp.	108	10.3	1,858.3	39.2	5,810.4	53.8	53.8

respect to number of individuals in the food of trout Cottidae ranked first in importance, *Notropis* second, Coregonidae third, and *Pungitius* fourth. On the basis of actual volume the Cottidae were still the most important, but the Coregonidae moved to second place, *Notropis* dropped to third, while *Pungitius* retained the last position. With respect to calculated volume, however, the Coregonidae ranked first in significance and Cottidae second, the former making up 67.5 per cent and the latter only 20.8 per cent of the total calculated volume of fish food. From these computed percentages it would appear that the Coregonidae were of much greater value as food to the lake trout than was revealed by a direct evaluation of the stomach contents.

There were only two principal groups of fishes eaten by the lawyers—Cottidae and Coregonidae (Table 10). With respect to numbers of individuals consumed Cottidae constituted 89.7 per cent and Coregonidae 10.3 per cent of the total, with a proportionate actual volume of 60.8 and 39.2 per cent respectively. When, however, the theoretical volume of the food prior to digestion is calculated the Coregonidae assumed a much more important role (53.8 per cent) while the Cottidae decreased in proportionate value (46.2 per cent). On the basis of computed volumes the Coregonidae were more valuable than any other species of fish as food to the lawyer. (The average volume per individual cottid, 5.3 milliliters, was based on 33.1 per cent *Cottus* spp. with an average volume of 2.6 milliliters and 66.9 per cent *Triglopsis thompsonii* with an average volume of 6.7 milliliters.)

Summary and Conclusions

1. This paper reports on the analysis of 593 lake trout stomachs and of 172 lawyer stomachs examined in the field in 1930, and of 4,386 lake trout and 1,356 lawyer stomachs examined or preserved in 1931 and 1932, a grand total of 4,979 lake trout and 1,528 lawyer stomachs taken from Lake Michigan fish. The specimens were taken on various dates during the period, April 28-November 14, in water that ranged from 14 to 101 fathoms in depth (84-606 feet). In the treatment of the data the lake was divided into three general regions (southern, northern, and Green Bay) and the trout or lawyers of each region considered a unit with respect to food habits. Inspection of the data showed that the trout or lawyer of each region had very similar feeding habits—there were no significantly consistent variations in food composition with the localities within a region in spite of the fact that the feeding habits of the trout and lawyers were found to vary with the length of the fish, with the depth of water from which they were taken, and with the season of the year.

2. Because the specimens whose stomach contents were analyzed were captured in small-meshed gill nets with meshes measuring from 2⅜ to 3 inches, stretched measure, they represented principally the

small and medium-sized individuals of the population. Fifty-three per cent of the trout were males and 47 per cent were females. Ninety-nine and six tenths per cent of the male and 99.3 per cent of the female trout were sexually immature. In 1931 some 61 per cent of the lawyers were males, 39 per cent were females but in 1932 the sex ratio was 50-50. The ratio for both years combined was 56 males, 44 females. In 1931 some 97 per cent of each sex were sexually mature, but in 1932 only 82 per cent of the males and 74 per cent of the females were mature.

3. The following groups were represented in the food of the lake trout from Lake Michigan: MOLLUSCA: *Musculium* sp.; CRUSTACEA: *Pontoporeia* and *Mysis;* INSECTA: grasshoppers, dragonflies, beetles, midge larvae, and carpenter ants; FISHES: Osmeridae (smelt), Coregonidae (principally chubs), Cyprinidae (lake shiner), Percopsidae (trout-perch), Percidae (perch, log perch, darter), Cottidae (sculpins, miller's thumb), and Gasterostidae (nine-spined stickleback). Fewer groups were represented in the food of the lawyers: CRUSTACEA: *Pontoporeia, Mysis,* crayfish; INSECTA: beetles; FISHES: Osmeridae, Coregonidae, Percopsidae, Percidae (yellow perch), Cottidae, Gasterostidae.

4. The percentages of stomachs which contained no food were rather large (44.3 in the trout, 16.6 in the lawyer) due in part to the length of time which elapsed between the capture and the removal of the fish from the nets.

5. Because the stomach contents collected in 1930 were not as completely analyzed as those collected in 1931 and 1932, the 1930 data are given in summary form only. The discussion on food is based almost entirely on the materials collected in 1931 and 1932. Fishes were found in 93.4 per cent of the trout stomachs, invertebrates (mainly *Mysis*) in only 6.7 per cent. In southern Lake Michigan, Cottidae occurred in 73.2 per cent of the stomachs, Coregonidae in only 10.2 per cent. In northern Lake Michigan 34.3 per cent of the trout had taken Cottidae, 27.2 per cent Coregonidae, and 18.1 per cent *Pungitius.* In Green Bay 51.6 per cent of the trout stomachs contained *Notropis atherinoides,* 13.2 per cent *Cottus,* and 9.7 per cent Coregonidae. About 85 per cent of the lawyers taken in southern Lake Michigan and Green Bay had fed on fishes but only 35.6 per cent of those collected in northern Lake Michigan had done so. The dominant forms were Cottidae and Coregonidae. A considerable percentage of the lawyers had taken *Mysis* in the southern and Green Bay areas of the lake and *Pontoporeia* in the northern region.

6. Of the total volume of food found in the stomachs of the lake trout, 98.3 per cent consisted of fish and only 1.8 per cent of invertebrates. The stomach content of the lawyers was made up of 74.3 per cent by volume of fish and 25.7 per cent invertebrates, mostly *Pontoporeia.* Although the general conclusions based on the per-

centages of the total number of stomachs analyzed agreed with those based on percentages by volume, the relative importance of the various food forms did not always remain the same within a region. On the basis of percentage by volume the Coregonidae usually outranked the Cottidae or crustacea in importance, although on the basis of percentage by number the reverse was true.

7. The number of individuals of each species of fish used as food and the percentage composition by number are given to show predator relationships. Except in northern Lake Michigan the number of commercially important Coregonidae destroyed by the lake trout and lawyer was relatively small.

8. When the theoretical volume of the fish in the food before digestion is calculated from the known volume of an individual of average size the Coregonidae become the most important food item, providing 67.5 per cent of the total volume of fish consumed by the lake trout and 53.8 per cent of the theoretical volume consumed by the lawyer.

9. The lake trout and lawyers were competitors for the same food and were predatory on the commercially valuable Coregonidae, principally chubs and lake herring.

10. The commercially unimportant lawyer, through the consumption of small crustaceans, is a great food competitor of the common whitefish, the round whitefish, and possibly some of the chubs in waters where these species occur.

11. No evidence was found that the lawyer and lake trout feed on each other. The absence of such evidence may have been due to the inclusion of the stomachs of only a very few large individuals of both species in the collections. The smelt was not eaten by lake trout or lawyers from Lake Michigan proper and occurred in the stomachs of only eight lake trout and one lawyer from Green Bay.

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A PRELIMINARY ACCOUNT OF THE FISH POPULATIONS IN CERTAIN NOVA SCOTIAN LAKES*

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Abstract

An analysis of the fish populations in three Nova Scotian lakes, as revealed by a copper sulphate treatment designed to eradicate the predatory fish, is presented. An acid lake of 55.8 acres produced a total estimated population of 27,770 fish or 17.0 pounds per acre; a slightly acid lake of 52.0 acres produced a population of 86,217 fish or 36.0 pounds per acre; and another lake of 45 acres gave an estimated population of 35,025 fish or 19.9 pounds per acre.

In three Nova Scotian lakes the fish populations have been destroyed by adding copper sulphate to the waters (approximately 3 p.p.m.). By this procedure, carried out in each lake by the Fish Culture Branch of the Canadian Department of Fisheries, the predators and competitors of speckled trout have been killed, and thus it is anticipated that in these lakes more suitable areas for planting trout fry will have been provided, as soon as the food organisms, also killed by the copper sulphate, return in sufficient quantities. Lake Jesse was treated in 1934, and accounts of the procedure, as there applied, have already been published (Catt, 1934; Smith, 1935a). Trout fry were planted in this lake in the spring of 1936. In early May, 1937, angling showed the presence of 6- to 8-inch fish. In late July and early August, 1936, Tedford and Boar's Back lakes, situated in the same region of Nova Scotia, were also treated with copper sulphate in the same manner as Lake Jesse.

Although the copper sulphate treatment of the Nova Scotian lakes is primarily an attempt to obtain an effective procedure for replenishing by fry planting the speckled trout stock of small and medium sized lakes, one is able to acquire valuable information on the standing fish crops, as well as random samples for more intensive studies on the status of several species of fish. In this article, it is my intention to present estimations of the fish populations in the three lakes in question. Data on the fish in Lake Jesse have already been published in a preliminary report (Smith 1935b), but are here reviewed for comparison.

Methods of Making the Estimations

The fish were counted as they entered several measured areas along the shore of each lake. Knowing the total length of the shore-line, an estimation of the total population was thus possible. In Boar's Back lake the fish were enumerated on 18.1 per cent of the total

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shore-line, in Tedford, on 19.3 per cent, and in Jesse, on 9.1 per cent. Observations made off-shore, wherever the bottom could be seen, indicated that almost all the fish moved into the shore areas, either by swimming or by floating in.

The weight of the fish was obtained from samples preserved in formalin. These collections were secured by taking the fish that came into certain areas, which were smaller than those in which the fish were counted. The weighing was done after the fish had been preserved for about five months. Possibly the weights herein presented will need correction when it has been determined for the several species of fish that a change in weight occurs during preservation.

A certain number of fish survived the copper sulphate treatment. Work at Lake Jesse indicated, however, that the survivals constituted only a very small percentage of the total numbers. A second treatment is essential to determine accurately the actual number that does survive, as well as to gauge the success of the method for de-populating waters of fish.

Descriptions of the Lakes

Boar's Back Lake—(55.8 acres). Boar's Back Lake has an average depth of 8.5 feet in summer. There is one depression, very restricted in area, which drops to a maximum of 31 feet. Two outstanding characters of the water are its deep brown color ("bog" water) and its high acidity (pH 4.3 to 4.5). As a result of the high acidity no mollusks occur in the lake. On August 10, 1936 the water had the following dissolved oxygen content and temperatures: at the surface, 4.96 cubic centimeters per liter and 23.5° C.; at a depth of 13.1 feet (4 meters), 4.85 cubic centimeters per liter and 17.5° C.; at a depth of 26.2 feet (8 meters), 2.64 cubic centimeters per liter and 15.4° C. The bottom, except for a narrow zone around the shores where a rubble predominates, is composed of a soft ooze. The rooted emergent aquatic vegetation is limited to a number of small beds of *Nymphaea advena* and scattered growths of *Eriocaulon*. The lake is about three times as long as wide.

Tedford Lake (52.0 acres). The average depth of water in summer is 8 feet, with a maximum of 20 feet. In summer the water is clear, but it becomes stained with increased drainage, particularly in spring and fall during which periods the pH value of the water is lowest (5.6 on May 5, 1937; 5.8 on November 5, 1936). On July 29, 1936 pH values of 6.3 to 6.4 were obtained. On the same date, the surface water contained 5.48 cubic centimeters of dissolved oxygen per liter at a temperature of 20.5° C.; at 8.2 feet (2.5 meters), the oxygen content was only slightly lower being 5.34 cubic centimeters per liter at a temperature of 20.3° C.; and the oxygen content equalled 5.23 cubic centimeters per liter at 11.5 feet (3.5 meters) at a temperature of 20.3° C. A large amount of emergent aquatic vegetation and beds of *Castalia, Nymphaea, Juncus, Scirpus, Eriocaulon* and

Pontederia cover about one-fifth of the total bottom area. The bottom is composed principally of a soft ooze.

Lake Jesse (45 acres). The average depth of water is 8 feet with a maximum depth of 21.5 feet. The water is usually quite clear. The recorded pH values range from 5.7 to 6.0 in the spring and fall to 6.6 in August. The dissolved oxygen content at the surface on August 4, 1934 was 6.81 cubic centimeters per liter at a temperature of 24.4° C. and at a depth of 18 feet, 5.66 cubic centimeters per liter at 21.4° C. As in the other two lakes the bottom in the deeper water is made up of a soft ooze. There is little rooted emergent vegetation, and such that does exist is composed principally of *Nymphaea, Pontederia* and *Eriocaulon.*

The Fish Populations

In Table 1 estimations of the total number of fish in each lake are presented, as well as the number per acre and the poundage per acre. These estimations are made for each species that was found to occur in the lakes, although in a few species the number was too small to provide one per acre or 0.1 pound per acre.

Approximately 28,000 fish were killed in Boar's Back Lake, 86,000 in Tedford, and 35,000 in Jesse. The majority of the fish were small, so that the resultant poundage per acre, considering the number of fish, appears small. In Boar's Back Lake, *Catostomus* was an exception, for although there were estimated only seven fish per acre, this species gave the greatest poundage per acre in this lake, namely 8.1. There was a total of 17.0 pounds per acre in Boar's Back Lake, of 19.9 pounds per acre in Lake Jesse, and of 36.0 pounds per acre in Tedford Lake.

Discussion

Is the estimated production for these three lakes high or low? Compared to an estimation made by Viosca (1935) for a small Louisiana pond (0.1 acre), which gave 860 pounds per acre, 17 to 36 pounds per acre is definitely low. As Viosca indicates, however, the yields are probably higher in warmer climates than in the colder, due to speeding up of the turnover of organic materials, and of the rates of growth of fish. For a small Michigan lake (4.3 acres, with a maximum depth of 42 feet), Eschmeyer (1937) reports an estimation of 30 pounds, or 955 fish per acre, a quantity which is of the same order as found in the Nova Scotian lakes studied. The population in the Michigan lake consisted entirely of yellow perch, except for a very few introduced speckled trout, and was determined after poisoning.

It would appear, from such data as have been reported, that the standing crop of fish in streams, as a whole, runs higher than in lakes. Thus Viosca (1935) estimates the total standing crop of all species in spring-fed creeks in south Louisiana at 300 to 500 pounds per

TABLE 1. NUMBER AND WEIGHT OF FISH KILLED IN THREE NOVA SCOTIAN LAKES

Species	Boar's Back Lake				Tedford Lake				Lake Jesse			
	Total number	Number per acre	Number used for weight	Pounds per acre	Total number	Number per acre	Number used for weight	Pounds per acre	Total number	Number per acre	Number used for weight	Pounds per acre
Salvelinus fontinalis (Brook trout)	23	—	20	0.1	—	—	—	—	29	1	5	0.4
Notemigonus crysoleucas (Golden shiner)	1,071	19	54	0.4	7,922	152	708	2.7	2,611	58	111	2.0
Semotilus atromaculatus (Creek chub)	—	—	—	—	—	—	—	—	22	—	—	—
Catostomus commersonii (Common sucker)	364	7	19	8.1	—	—	—	—	22	—	—	—
Ameiurus nebulosus (Bullhead)	2,114	38	45	4.1	1,691	33	116	5.5	1,179	26	21	5.1
Anguilla rostrata (Eel)	293	5	12	0.2	2,822	54	108	2.3	1,095	24	29	0.7
Fundulus diaphanus (Killifish)	1,275	23	91	0.2	42,621	820	2,297	5.8	10,098	224	325	1.6
Perca flavescens (Yellow perch)	22,630	406	822	3.9	7,383	142	573	2.0	14,177	315	497	4.6
Morone americana (White perch)	—	—	—	—	23,726	456	1,349	17.7	5,781	128	229	5.5
Pungitius pungitius (Stickleback)	—	—	—	—	52	1	6	—	11	—	—	—
TOTALS	27,770	498	1,063	17.0	86,217	1,658	5,157	36.0	35,025	776	1,227	19.9

acre. For small Illinois streams, Thompson and Hunt (1930) compute about 150 pounds per acre. Greeley (1934, 1935, and 1936), from counts made on one-hundred foot stretches of small trout streams in New York State, presents a number of estimations varying from 16.7 to 247.6 pounds per acre.

In contrast to the above, the annual yield of carp in German and Japanese rearing ponds, rice fields, or in some fertilized waters, may run to several hundred-weight or even tons per acre (Viosca, 1935).

The number of fish and the poundage per acre in the Nova Scotian lakes, as revealed by the copper sulphating (Table 1), show considerable variation from lake to lake. The variations, which one should probably expect in natural waters, can be correlated in these lakes with differences in the chemical and biological conditions. As indicated above, the water in Boar's Back Lake is decidedly more acid than in the other lakes, and this feature is correlated with a lower production, more particularly apparent in the number of fish than in the poundage per acre. The high acidity of this lake prevents the occurrence of mollusks, and, in general, it may be said that the amount of bottom fauna was less here than in Tedford Lake. (Bottom samples have been collected, but not yet analyzed.) The highest production of fish, that is in Tedford Lake, is also correlated with the greatest development of rooted emergent aquatic vegetation, and in this regard Tedford differs strikingly from Lake Jesse, although in physical and chemical conditions the two lakes are quite similar. This difference holds between Tedford and Boar's Back. Beds of rooted aquatics provide suitable areas for the growth of a large number of invertebrate fish-foods, and where the development of this type of vegetation occurs in conjunction with suitable waters for fish, the production of fish is undoubtedly increased. This correlation between a larger fish crop and a larger quantity of rooted vegetation is in direct agreement with postulates made by Klugh (1926), that the best production in lakes generally co-exists with an abundance of aquatics.

The purpose of the copper sulphate treatment, as already indicated, is to create more suitable conditions for populating small lakes with game fish, in the Nova Scotian lakes with speckled trout. In this respect the small number of trout found in the three lakes is of particular interest. There were no trout in Tedford Lake and only twenty-nine in Lake Jesse, although the angling history of both lakes shows good catches until recent years. As with many, if not most, of our angling waters, these lakes were heavily fished. Little is known of the past fishing conditions in Boar's Back Lake, but in any case only twenty-three trout were killed by the poisoning. Also of importance is the fact that no trout fry were taken. Fish of the year belonging to other species were, however, encountered. In contrast to the meagre number of trout was the dominance of yellow and

white perch, both predators and competitors of the trout. Overfishing for trout would remove one check on the increase of perch, and would tend to lead to perch-dominance, which in its turn would prevent success in stocking these lakes with trout fry. There may have been a number of other factors contributing to the scarcity of trout, such as competition with a large number of *Fundulus, Anguilla,* or *Notemigonus,* but it is our contention that over-fishing and increases in the perch populations were the major factors involved. This brief analysis of the relative abundance of the various species of fish clearly demonstrates the need for removal and control of predators and competitors, such as perch.

Obviously a lake will support only a certain number of fish, and for the Nova Scotian lakes investigated the poundage per acre is not large. Nevertheless, assuming that the lakes will be as productive after the copper sulphate treatment as they were before (there are indications that in Lake Jesse the zooplankton crop is greater), the replacement of the undesirable species by trout will provide 18 to 36 pounds of this prized fish per acre. Such production means good trout angling and it is not out of the bounds of reason to look forward to that result.

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OBSERVATIONS ON THE SALMON PARR OF THE MARGAREE RIVER

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In 1934 at the suggestion of Dr. A. G. Huntsman, of the Biological Board of Canada, a study of the salmon parr in several sections of the Margaree River (Cape Breton, N. S.) was made. The results of our observations on the age, growth, and characteristics of these parr are presented in this paper. The original purpose of the study was to compare the age, growth, and characteristics of the parr from various parts of a single river system with particular reference to the effect of environment.

THE MARGAREE RIVER

The Margaree River, one of the famous salmon rivers of Nova Scotia, is located in the western part of Cape Breton. It consists of two branches, the larger, the Northeast Margaree and the smaller, the Southwest Margaree. These branches unite at Margaree Forks to form the main river, which flows in a northerly direction through fertile farm land for a distance of 7 miles to enter the Gulf of St. Lawrence at Margaree Harbor. The lower 3 miles of the river are tidal.

The Southwest Margaree has its source in a large body of water, Lake Ainslee. Its ten and one-half mile course from the outlet of the lake to its junction with the Northeast Margaree at Margaree Forks lies through open farm land. Its water supply is derived chiefly from Lake Ainslee, although it is augmented by numerous spring-fed brooks along its course. Because of its source the Southwest Margaree has a summer temperature several degrees higher than the Northeast Margaree. The natural food supply of the parr is greatly increased by plankton from the lake and by terrestrial insects from the adjoining farm land.

The Northeast Margaree has its source in the mountains some 25 miles northeast of Margaree Forks. During the first 15 miles of its course it is a rapid mountainous and upland stream, fed by large tributary brooks. For the remainder of its course from Frizzleton to Margaree Forks the river, like the Southwest Margaree, flows through farm land, and receives several large tributary brooks.

Four sections of the Margaree River were selected for a comparative study of the parr: (1) the Southwest Margaree 2 miles above its junction with the Northeast Margaree, (2) Forks Pool in the main river just below the junction of the two branches, (3) the Lower Northeast Margaree one-half to two miles above its junction with the Southwest Margaree, and (4) the Upper Northeast Margaree below Forest Glen Brook. Nearly all the Lower Northeast Margaree parr

were obtained from Garden Pool, and those of the Upper Northeast Margaree from Breakwater Pool and Old Bridge Pool. Parr were also obtained from Forest Glen Brook and Mill Brook, tributaries of the Northeast Margaree.

The environment of these sections differs in several respects. The Southwest Margaree, Forks Pool, and the Lower Northeast are situated in farming country, while the Upper Northeast Margaree and the tributaries flow for the most part through woodland. When arranged according to magnitude with respect to the volume of water the order is: Forks Pool, Lower Northeast Margaree, Southwest Margaree, Upper Northeast Margaree, and tributaries. When arranged with respect to the abundance of parr food, the order is Southwest Margaree, Forks Pool, Lower Northeast Margaree, Upper Northeast Margaree, and tributaries. The water temperature during the summer is highest in the Southwest Margaree, somewhat lower in Forks Pool, and several degrees lower in the Lower Northeast and Upper Northeast Margaree.

Methods of Investigation

Collection of Parr. The parr were taken by seining at night about September 1, 1934. In large rivers night seining is the most practical method of insuring a fair sampling, since parr of all sizes gather along the banks at night, presumably for the purpose of feeding. The age and distribution of the 1,491 parr thus collected are given in Table 1.

All measurement and weight determinations were made on parr preserved in formaldehyde. In order to conform to the two methods of measuring adult salmon in Canada and in Europe two length measurements were made: (1) the total length from the snout to a point midway between the two extremities of the tail, and (2) the mid-tail or fork length from the snout to the end of the mid-spine of the tail. The total and mid-tail lengths are expressed in millimeters and the weights in grams.

From the weight and length the coefficient of condition of the parr may be calculated according to the formula of Menzies, in which the coefficient of condition is equivalent to one hundred times the weight in grams divided by the cube of the length in centimeters. Since the coefficient of condition depends upon the solidity of the flesh or upon the contour of the parr, it is of value in comparing the parr of different rivers.

Scale Readings. The scales were taken from the shoulder of the parr just anterior to the beginning of the dorsal fin and halfway between the lateral and the mid-dorsal lines. The river years were determined by the winter bands in the same way as the sea-life years of the adult salmon.

Length Calculations. Over any appreciable length of time the scale increases in size proportionally to the growth of the parr. It is pos-

sible, therefore, by knowing the length of the parr, to calculate its size at yearly intervals, by measuring the distances from the center of the scale to the anterior edge and to the outer edge of each winter band. Ten well-formed scales were measured for each parr. In calculating the yearly lengths both the scale proportional and the scale length ratio methods described by Belding (1934) were employed.

Distribution of Salmon Parr According to Ages

The distribution of parr according to river ages in Table 1 gives an approximate idea of the relative abundance of the 1931, 1932, 1933, and 1934 year classes in the several sections of the Margaree River. Since the hatches of different years vary in abundance, these figures may not represent true averages for other years. Likewise the selection of locality and manner of collection may not give a representative sampling of the age classes.

Practically no 2-plus parr were found in the Southwest Margaree, in Forks Pool, or in the Lower Northeast Margaree, indicating that most of the parr had left the river as smolt at or before the end of the second year. The proportion of 0-plus parr to 1-plus parr differed widely in the different sections; in the Lower Northeast Margaree it was approximately 3 to 1, in the Forks Pool 4 to 1, and in the Southwest Margaree 10 to 1. The marked difference between the Southwest Margaree and the Lower Northeast Margaree suggests a sectional variation in the 1934 hatch or a large proportion of 1-year smolt in the Southwest Margaree.

TABLE 1. AGE OF SALMON PARR IN THE MARGAREE RIVER

Sections of Margaree River	Number of parr	Number in age group				Percentage in age group			
		0+	1+	2+	3+	0+	1+	2+	3+
Southwest	221	201	19	1	----	90.9	8.6	0.5	----
Forks Pool	265	214	50	1	----	80.8	18.8	0.4	----
Lower Northeast	698	514	182	2	----	73.6	26.1	0.3	----
Upper Northeast	252	150	85	16	1	59.6	33.7	6.3	0.4
Tributaries Northeast	55	15	27	11	2	27.3	49.1	20.0	3.6
Total or Average	1,491	1,094	363	31	3	73.4	24.3	2.1	0.2

Age of Smolt

Table 2 gives the approximate age of the smolt in the various sections of the Margaree River, as estimated from the frequency distribution of the length for the several age groups of parr and from the numerical proportion of each age group. The composite age of the smolt for the entire Margaree River is estimated from the relative area of and number of parr in the various sections of the river and its tributaries.

In the Southwest Margaree and in Forks Pool, except in the tributary brooks, the parr rarely remain over two years in the river. In

the Lower Northeast Margaree about one-eighth remain for three years. In the Upper Northeast Margaree over four-twelfths leave the river at the end of two years, seven-twelfths at the end of the third year, and less than one-twelfth at the end of the fourth year.

TABLE 2. PERCENTILE DISTRIBUTION OF SMOLT AGES

Sections of Margaree River	River years 1	2	3	4	Average years in river
Southwest	21	78	1	0	1.80
Forks Pool (Main River)	2	97	1	0	1.99
Lower Northeast	1	87	12	0	2.11
Upper Northeast	0	36	58	6	2.48
Tributaries Northeast	0	33	57	10	2.77
Entire Margaree River	4	68	25	3	2.27

Length of the Margaree Parr

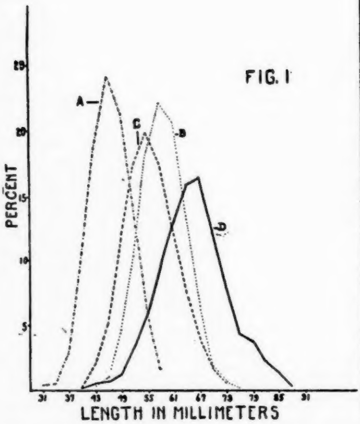
Mean Length. The average lengths, both total and mid-tail, of the parr in the several sections of the Margaree River are given in Table 3. Since little or no increase in length takes place after September 1, the date of capture, these figures for all practical purposes represent the size of the parr at the completion of the full year's growth; for example, the 0-plus parr equal 1 year, the 1-plus parr 2 years, etc.

There is a wide diversity of growth in both 0-plus and 1-plus parr in the several sections of the river. The largest parr are found in the Southwest Margaree and the smallest in the tributaries of the Northeast Margaree. The parr of the Upper Northeast Margaree and tributaries of the Northeast Margaree are approximately of the same size, and are smaller than the parr of the Lower Northeast Margaree, which in turn are considerably smaller than the parr of

TABLE 3. LENGTHS AND WEIGHTS OF SALMON PARR OF MARGAREE RIVER

Section of Margaree River	Number	Total length (millimeters)	Mid-tail length (millimeters)	Weight (grams)
0-plus parr				
Southwest	201	65.57 ± 0.36	61.49 ± 0.35	2.86 ± 0.05
Forks Pool	214	55.80 ± 0.25	52.19 ± 0.24	1.70 ± 0.02
Lower Northeast	514	58.61 ± 0.14	54.77 ± 0.13	1.78 ± 0.01
Upper Northeast	150	46.83 ± 0.23	43.95 ± 0.22	0.92 ± 0.01
Tributaries Northeast	15	46.53 ± 0.89	43.27 ± 0.71	0.86 ± 0.05
1-plus parr				
Southwest	19	140.32 ± 3.18	130.68 ± 2.86	28.22 ± 1.87
Forks Pool	50	118.76 ± 1.20	109.86 ± 1.16	16.79 ± 0.56
Lower Northeast	182	107.51 ± 0.56	99.35 ± 0.52	11.37 ± 0.19
Upper Northeast	85	91.05 ± 0.65	84.38 ± 0.58	6.80 ± 0.15
Tributaries Northeast	27	90.00 ± 0.92	83.15 ± 0.92	6.56 ± 0.21
2-plus parr				
Upper Northeast	16	121.69 ± 1.05	112.94 ± 1.00	16.36 ± 0.39
Tributaries Northeast	11	117.55 ± 1.43	109.27 ± 1.32	15.04 ± 0.72

the Southwest Margaree. The 0-plus parr of the Forks Pool provide an exception to a graded series. These parr of the 1934 year class are smaller than those of the Lower Northeast Margaree, and their length is appreciably less than the calculated length of the 1933 year class (Table 6). Since the number, 214, is sufficiently large to eliminate faulty sampling, some local peculiarity in the 1934 hatch is the probable explanation of this phenomenon.



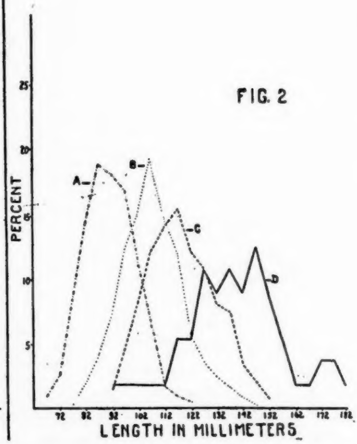


Figure 1.—Percentile Frequency Distribution of Total Lengths of 0-plus Parr of the Margaree River.
A. Upper Northeast Margaree River
B. Lower Northeast Margaree River
C. Forks Pool (Main Margaree)
D. Southwest Margaree River

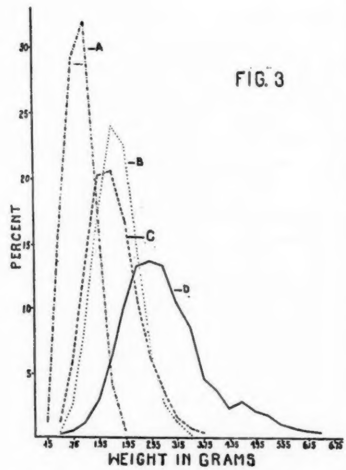
Figure 2.—Percentile Frequency Distribution of Total Lengths of 1-plus Parr of the Margaree River.
A. Upper Northeast Margaree River
B. Lower Northeast Margaree River
C. Forks Pool (Main Margaree)
D. Southwest Margaree River

Frequency Distribution. Figures 1 and 2 show graphically the percentile frequency distribution of lengths for the 0-plus and 1-plus parr of the different sections. This graphic presentation shows even more strikingly than the mean lengths the differences in the growth of the parr in the various parts of the river.

Total vs. Mid-tail Length. For the 0-plus and 1-plus parr the mid-tail length, when plotted against the total length, gives a straight line. The difference between the two lengths may be expressed by the straight line equation, $D = 0.0827L - 0.986$. From this equation the difference (D) between mid-tail length and total length for any particular total length (L) may be determined.

WEIGHT OF THE MARGAREE PARR

Mean Weight. The average weight for the various aged parr of the several sections of the Margaree River is given in Table 3. A comparison of the weights shows even more strikingly than that of the lengths the difference in the size of parr in the several sections. Little difference is found in the Upper Northeast Margaree and the tributaries of the Northeast Margaree.



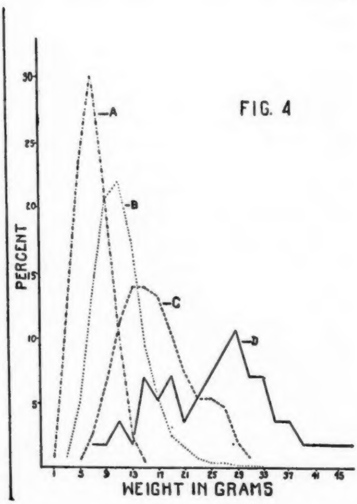


Figure 3.—Percentile Frequency Distribution of Weights of 0-plus Parr of the Margaree River.
A. Upper Northeast Margaree River
B. Lower Northeast Margaree River
C. Forks Pool (Main Margaree)
D. Southwest Margaree River

Figure 4.—Percentile Frequency Distribution of Weights of 1-plus Parr of the Margaree River.
A. Upper Northeast Margaree River
B. Lower Northeast Margaree River
C. Forks Pool (Main Margaree)
D. Southwest Margaree River

Combining the 0-plus and 1-plus parr, the weight of the Lower Northeast Margaree parr is 1.8 times that of the Upper Northeast Margaree parr, that of the Forks Pool parr 2.2 times, and that of the Southwest Margaree parr 3.8 times.

Frequency Distribution. Figures 3 and 4 show the percentile frequency distribution of weights for the 0-plus and 1-plus parr in the several sections of the river. The difference in the size of parr in these sections is clear cut. The fast growing parr of the Southwest Margaree give a low wide frequency distribution curve.

Coefficient of Condition

Table 4 gives the coefficient of condition, as calculated by Menzies' formula, for both the total length and mid-tail length. The coefficient of condition when calculated from the average length and weight is higher than when the mean of the individual parr coefficients is obtained.

The coefficient of condition increases slightly with the age of the parr. An average of all the sections of the river for total length and mid-tail length as determined from the average length and weight and from the mean of the individual parr gives 1.018 for the 0-plus parr and 1.053 for the 1-plus parr, an increase of 3.4 per cent. For the two river sections with the older parr the coefficient of condition is 0.868 for the 0-plus parr, 0.892 for the 1-plus parr and 0.914 for the 2-plus parr.

The coefficient of condition is not dependent on the rate of growth; for example, the Upper Northeast Margaree parr have a slower

TABLE 4. COEFFICIENT OF CONDITION

Section of Margaree River	Number	Total length (millimeters)		Mid-tail length (millimeters)	
		Calculated from average length and weight	Calculated as mean of individual parr values	Calculated from average length and weight	Calculated as mean of individual parr values
0-plus parr					
Southwest	201	1.014	0.986 ± .004	1.230	1.195 ± .005
Forks Pool	214	0.979	0.952 ± .004	1.196	1.164 ± .005
Lower Northeast	514	0.886	0.876 ± .003	1.083	1.073 ± .004
Upper Northeast	150	0.896	0.879 ± .005	1.082	1.064 ± .006
Tributaries Northeast	15	0.854	0.841 ± .017	1.063	1.050 ± .028
1-plus parr					
Southwest	19	1.021	0.965 ± .010	1.264	1.189 ± .012
Forks Pool	50	1.002	0.964 ± .006	1.266	1.220 ± .007
Lower Northeast	182	0.915	0.891 ± .005	1.159	1.130 ± .006
Upper Northeast	85	0.901	0.881 ± .006	1.132	1.106 ± .007
Tributaries Northeast	27	0.899	0.883 ± .010	1.140	1.120 ± .012
2-plus parr					
Upper Northeast	16	0.908	0.905 ± .014	1.136	1.124 ± .018
Tributaries Northeast	11	0.926	0.916 ± .020	1.153	1.134 ± .016

growth than the parr of the Lower Northeast Margaree, yet they have approximately the same coefficient of condition. Conversely the 0-plus parr of the Forks Pool have even slower growth than the parr of the Lower Margaree but a higher coefficient of condition.

The coefficient of condition evidently depends on environmental conditions. The high figures for the Southwest Margaree and Forks Pool, in contrast with the Lower Northeast Margaree, suggest primarily temperature and secondarily food supply as important factors.

Table 5 gives the weight and coefficient of condition for the total lengths of 0-plus parr. There is considerable difference in the weight of the parr of the same length for the several sections of the river. It is interesting to note that in the frequency distribution of lengths for a definite age group such as the 0-plus parr the coefficient of condition is higher for the small, slowly growing fish and lower for the larger, fast growing fish.

TABLE 5. LENGTH AND WEIGHT OF 0-PLUS PARR*

	Weight (grams)				Coefficient of condition			
Total length (millimeters)	Southwest	Forks Pool	Lower Northeast	Upper Northeast	Southwest	Forks Pool	Lower Northeast	Upper Northeast
40	(1.09)	(0.68)	(0.76)	0.68	(1.703)	(1.063)	(1.188)	1.063
43	(1.15)	(0.80)	(0.85)	0.76	(1.446)	(1.006)	(1.069)	0.956
46	(1.24)	(0.95)	(0.98)	0.88	(1.274)	(0.976)	(1.007)	0.904
49	(1.37)	1.13	(1.12)	1.02	(1.164)	0.960	(0.952)	0.867
52	1.54	1.34	1.30	1.20	1.095	0.953	0.925	0.853
55	1.75	1.58	1.49	1.40	1.052	0.950	0.896	0.841
58	1.99	1.85	1.72	(1.63)	1.020	0.948	0.882	(0.835)
61	2.28	2.16	1.96	(1.89)	1.004	0.952	0.864	(0.833)
64	2.60	2.49	2.23	(2.17)	0.992	0.950	0.851	(0.828)
67	2.96	2.85	2.53	(2.49)	0.984	0.948	0.841	(0.828)
70	3.35	(3.24)	2.85	(2.83)	0.977	(0.945)	0.831	(0.825)
73	3.79	(3.67)	(3.20)	(3.21)	0.974	(0.943)	(0.823)	(0.825)
76	4.26	(4.12)	(3.57)	(3.61)	0.970	(0.939)	(0.813)	(0.822)

*Figures in parentheses are based on the curve projected beyond actual data.

Calculated Lengths

Table 6 gives a comparison of the actual total lengths and the total lengths as calculated by scale measurement for the 1932, 1933, and 1934 year classes.

One Year. The calculated lengths for the 1933 year class and the actual lengths of the 1934 year class at one year agree closely in all the sections except the Forks Pool, in which the calculated lengths are considerably higher than the actual, and fall between the lengths of the Southwest and the Lower Northeast Margaree, their proper theoretical position. The calculated lengths of the year-old parr of the 1933 year class give the following order with respect to rapidity of growth: (1) tributaries of the Northeast Margaree 50.8 millimeters, (2) Upper Northeast Margaree 51.5 millimeters, (3) Lower

Northeast Margaree 57.5 millimeters, (4) Forks Pool 61.9 millimeters, and (5) Southwest Margaree 64.2 millimeters. An average of the calculated lengths of the 1933 year class and the actual lengths of the 1934 year class gives less than a millimeter's difference between the Forks Pool and the Lower Northeast Margaree. The calculated lengths probably represent the correct size of the parr in the several sections, and the average for the 1934 year class in Forks Pool for some unknown reason is abnormally low.

Two Years. The actual 2-year lengths show the same gradations as the calculated 1-year lengths for the several sections. The parr of the tributaries of the Northeast Margaree and of the Upper Northeast Margaree have about the same length but are much smaller than those in the other sections of the Margaree River. Since a considerable number of the larger parr leave as smolts at the end of two years, the calculated lengths of the 1932 year class at 1 and 2 years are lower than the normal length of parr at these ages and for this reason are not included in the average.

TABLE 6. LENGTH OF 1, 2, AND 3-YEAR-OLD PARR (Millimeters)

Sections of Margaree River	1934 year class 1 year	1933 year class 1 year*	1933 year class 2 years	1933 and 1934 year classes, average 1 year*	1932 year class 1 year*	1932 year class 2 years*	1932 year class 3 years
Southwest	65.6	64.2	140.3	64.9	——	——	——
Forks Pool	55.8	61.9	118.9	58.9	——	——	——
Lower Northeast	58.6	57.5	107.5	58.1	——	——	——
Upper Northeast	48.5	51.5	91.1	50.0	46.1	85.8	121.7
Tributaries Northeast	46.5	50.8	90.0	48.7	49.5	85.3	117.6

* = calculated lengths.

Growth. The mean length of the parr at one and two years illustrates the comparative rate of growth in the several sections of the Margaree River. The most rapid growth occurs in the Southwest Margaree, with its warm lake water and abundant food. The second fastest growth is found in the Forks Pool, where there is a mixture of the waters of the Southwest Margaree and Northeast Margaree. The third fastest growth is in the Lower Northeast Margaree, which flows through farm land. The slowest growth takes place in the wooded sections of the Upper Northeast Margaree and the tributaries of the Northeast Margaree.

Scale Length Growth Ratio. In general the scale increases in size proportionally to the increase in the length of the parr. If the length of the scale (S) is plotted against the total length (L) of the parr for a large number of specimens of each length, the result is approximately a straight line. The scale length growth ratio of the

parr in any section of a river may be expressed by a straight line formula, from which may be calculated the average length of scale for any sized parr. Since the growth of the parr differs in the various sections of the Margaree River, the equations for the several parts are different.

Southwest	$S = 0.05595L - 1.2456$
Forks Pool	$S = 0.05235L - 1.0702$
Upper Northeast	$S = 0.04416L - 0.8070$
Lower Northeast	$S = 0.04749L - 0.9298$
Tributaries Northeast	$S = 0.04877L - 0.9298$

Discussion

Conditions which affect the growth of parr are complex and it is difficult to isolate the effect of any single factor. A general idea of the influence of any factor may be obtained by comparing localities which show marked differences in this factor, but such methods may give misleading results.

Growth involves both linear and weight increase. The coefficient of condition is an expression of the sum total of the two. It is the result of the complex interplay between the rate of linear development and the effect of environment upon the form and weight of the parr. The coefficient of condition appears to be consistent for special parts of a river system, and should serve to define the growth-producing properties of a body of water.

Lake. The Southwest Margaree, Forks Pool in the main Margaree, and the Lower Northeast Margaree have the same riparian environment. Lake Ainslee supplies the Southwest Margaree with additional food and warmer water, the two factors which may account for the faster growth in the Southwest Margaree. It is a universal rule that rivers with large lakes produce larger parr.

Temperature. The higher temperature of the water in the Southwest Margaree appears to be the most prominent factor in determining not only the rapid increase in linear growth but also still greater gain in weight, as shown by a higher coefficient of condition than is found in the fish of the other sections of the Margaree River. Within limits, warm water not only increases the food supply but also stimulates metabolism. In rearing the salmon parr at hatcheries faster growth is obtained when the water temperature is raised over 60° F.

Food. Under favorable temperature and other conditions the growth of the parr is proportional to the abundance of food. The difference in growth between the Southwest Margaree, the Forks Pool, and the Lower Northeast Margaree cannot be explained by any marked variation in the food supply. On the other hand, the difference in growth between the Upper Northeast Margaree and the Lower Northeast Margaree appears to be largely due to the abundance of food.

Summary

1. The parr of different sections of the Margaree River show considerable variation in the rate of growth.

2. The average age of the smolt from the different sections of the Margaree River varied from 1.80 to 2.77 years.

3. The mean length of the 1-year parr in the several sections of the river ranged from 48.7 millimeters to 64.9 millimeters, and that of the 2-year parr from 90.0 millimeters to 140.3 millimeters.

4. The mean weight of the 1-year parr in the several sections of the river ranged from 0.86 gram to 2.86 grams, and that of the 2-year parr from 6.56 grams to 28.22 grams.

5. The coefficient of condition is an expression of the complex action of environmental factors and appears to be a fairly accurate measure of the growth-producing properties of any locality.

6. The rate of growth and coefficient of condition are the result of environmental conditions, among which the water temperature and food supply appear to be the most important.

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THE SALMON OF THE MOISIE RIVER

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This paper presents a brief characterization of the Atlantic salmon of the Moisie River, based upon material furnished through the courtesy of Mr. Ivers S. Adams, President of the Moisie Salmon Club. This river, one of the largest and most famous of the salmon rivers of the Province of Quebec, is located on the north shore of the Gulf of St. Lawrence east of Seven Islands. The main river is formed by two large streams, the East Branch and the West Branch, each of which receives several lake-fed tributaries. Below the junction of these branches the main river flows for 20 miles in a southerly direction as a wide, moderately rapid stream. It then narrows to one-third its previous width and flows swiftly for the next 4 miles through a series of five rapids and falls. Widening again, it passes the Main Camp of the Moisie Salmon Club, where it furnishes many fishing pools, and then continues south for 10 miles to enter the Gulf of St. Lawrence.

METHODS OF INVESTIGATION

The methods of investigation include: (1) an analysis of the records of the Moisie Salmon Club, (2) a review of the published and unpublished scale reading studies, and (3) observations on the growth of the salmon parr.

Moisie Salmon Club Records. The records of the Moisie Salmon Club furnish information as to (1) the individual weights of all salmon killed during the forty-year period from 1895 to 1934 inclusive, and (2) the number of salmon killed per rod-day for the thirty-three-year period from 1902 to 1934 inclusive. All the data deal with the salmon taken at the Main Camp of the Moisie Salmon Club.

Eliminating grilse, which are rarely found in the Moisie River, the salmon may be fairly accurately separated by the frequency distribution of weights into two classes: (1) 2-year sea-life salmon and (2) a composite group consisting of 3-year sea-life salmon, 4-year sea-life salmon, and previously spawned salmon. The differentiation between these groups is especially clear-cut, since there is little overlapping of the 2-year and 3-year sea-life salmon classes in the Moisie salmon, and only a small percentage of the previously spawned salmon fall in the intermediate zone. In this way the mean weight for the 2-year sea-life salmon and for the composite group of older salmon may be determined for each year. Experience in the analysis of the salmon of other rivers, where similar weight frequency classifications were checked by scale

reading, and supplementary observations upon the weights of the scale-read salmon of the Moisie River confirm the reliability of this method.

The Moisie Salmon Club records from 1902 to 1934 inclusive give the number of salmon killed each year and the number of days of fishing by each member. From this information the average catch per rod-day for each year with respect to the total salmon, the 2-year sea-life salmon and the older salmon may be determined. The high rod-day catch and the efficient method of recording the daily catch eliminate the complicating problem of zero fishing days. The rod-day catch gives a more accurate picture of the abundance of salmon than the total annual catch, which is dependent in a large measure upon the number of fishermen. Nevertheless, the rod-day average method is open to the objections that the length of the fishing day is not uniform and that it does not take into account intensity of fishing, season, and weather conditions.

From the number and mean weight of the annual catch, as separated into 2-year sea-life and older salmon, and from the rod-day catch it is possible to record the changes in the abundance and in the character of the salmon of the Moisie River over a period of years. The figures used in this paper do not represent the actual number of salmon, since the annual catch is expressed in terms of a total of 100,000 salmon for the forty-year period and the annual rod-day catch in terms of a total of 1,000 salmon per rod-day for the thirty-year period. This method of presentation permits accurate statistical treatment of the data without unnecessarily opening to public inspection the private records of the Moisie Salmon Club.

Scale Reading Studies. Scale readings of the Moisie River salmon were made by Gilbert (Unpub.) in 1919, 1920, and 1921, by Menzies (1926) in 1922 and 1923, by Menzies and Macfarlane (1928) in 1923 and 1924, and by Macfarlane (1928) in 1926 and 1927. Our scale reading on adult salmon has been confined to a small selected group of large fish, chiefly previously spawned salmon.

In spite of the accurate work of these investigators the collections of scales submitted for examination were not representative samples, since they contained too high a proportion of large fish. As a result the sea-life classes, as determined by scale reading, show an abnormally low percentage of 2-year sea-life salmon. From the Moisie Salmon Club records it has been possible to correct the sampling of the scale readings and to give a fairly exact picture of salmon stock for these years.

Salmon Parr. The parr were collected about 10 miles from the mouth of the river, near the Main Camp of the Moisie Salmon Club. The 1931 collection was taken on July 31 by fly rod and by daylight seining. The 1934 collection was made in September by seining at night. Since parr move to the shore at night, presumably for feeding, night seining gives the more accurate sampling of the various

year classes. Since little growth takes place after September 1, the 1934 parr show practically the full year's growth.

The parr were preserved in formaldehyde shortly after capture. Length, weight, and contour measurements were made later. Two measurements of length were made: (1) the total length from the snout to a point midway between the extreme tips of the tail, and (2) the mid-tail length from the snout to the end of the mid-ray of the tail. The length was measured in millimeters and the weight recorded in grams. The coefficient of condition was determined according to the method of Menzies, using the formula

$$K = \frac{100 \times \text{weight (in grams)}}{\text{Length (in centimeters)}^3}$$

The river age of the parr was determined by the enumeration of winter bands in the same manner as in the scales of adult salmon. The scales were taken above the lateral line from the region below the anterior end of the dorsal fin. Measurements from the center of the scale to the end of each winter band and to the edge of the scale were made on ten scales from each parr. From the length of the parr and of the scale the growth formula for the river was determined in the manner described by Belding (1932). The lengths of the parr at the ages of 1, 2 and 3 years of river life were calculated from these measurements by the scale proportion method and also by the scale length ratio method described by Belding (1934).

Sea-Life Classes of Moisie Salmon

Table 1 gives the composite data derived from the scale readings of the various investigators corrected for proper sampling of the catch.

TABLE 1. PERCENTILE DISTRIBUTION OF SEA-LIFE CLASSES OF MOISIE SALMON

Year	Number of salmon	Maiden salmon					Previously spawned salmon	Total
		1-year	2-year	3-year	4-year	Total		
1919	125	......	12.80	68.80	......	81.60	18.40	100.0
1920 and 1921	437	......	16.90	41.70	1.80	60.40	39.60	100.0
1922	131	......	11.40	65.70	0.80	77.90	22.10	100.0
1923	488	......	19.10	68.80	0.20	88.10	11.90	100.0
1924	173	0.60	40.40	34.70	0.60	76.30	23.70	100.0
1926	548	......	22.40	58.60	0.20	81.20	18.80	100.0
1927	442	......	8.60	69.70	0.20	78.50	21.50	100.0
Total	2,344	0.04	18.31	58.84	0.51	77.70	22.30	100.0

Grilse. Grilse are rare in the Moisie River, constituting but 0.04 per cent of the scale-read salmon and 0.04 per cent of the catch according to weight over a period of forty years. In a special study of ninety-one salmon, selected from the catches of several years be-

cause of their extremely large or very small size, two grilse and one salmon which had previously spawned as a grilse were found. Even granting the tendency of anglers to discard small fish, the number is surprisingly small, especially in view of the interest of the anglers during recent years in searching for these small salmon.

Two-year Sea-life Salmon. The annual percentage of maiden salmon which have spent two years in the sea varies markedly from year to year, ranging over a forty-year period from 7.7 to 51.3 per cent. In comparing the percentages from 1900 to 1934 there appears to be a certain five-year regularity in the peak years. By determining the ratio of each year to its geometric trend line value and obtaining the mean of these ratios for each of the five years, the presence of a cyclic tendency may be demonstrated, the peak falling on the zero and five years of the decade. Table 2 gives the relative values for each of the decade years. No satisfactory explanation is offered for this cyclic phenomenon.

TABLE 2. FIVE-YEAR CYCLE IN PERCENTAGE OF TWO-YEAR SEA-LIFE SALMON

Decade year	Relative value
0	140
1	106
2	69
3	74
4	103
5	140
6	106
7	69
8	74
9	103

By selecting five-year averages for the first and last parts of the decade it is possible to eliminate the influence of the cyclic phenomenon. The geometric trend, straight line trend, and actual values are given in Table 3. The geometric trend line indicates that there has been a fall in the percentage of 2-year sea-life salmon, reaching a depression peak about 1910, and that since that time there has been a progressive rise.

Calculations of the straight line and geometric trend lines indicate that the proportion of 2-year sea-life salmon is definitely on the increase. The significance of this fact is not clearly understood. Two explanations may be considered: (1) that the character of the Moisie salmon stock is changing, and (2) that this phenomenon is part of a long term cycle of which the period from 1900 to 1934 represents only a part. If the salmon stock is changing, the question arises as to whether the increasing proportion of the 2-year sea-life class should be interpreted as a sign of deterioration of the salmon of this river.

TABLE 3. PERCENTAGE OF TWO-YEAR SEA-LIFE SALMON BY FIVE-YEAR PERIODS, 1900-1934

Period	Percentage of two-year sea-life salmon		
	Actual	Straight line trend	Geometric trend
1900-1904	21.3	16.3	20.4
1905-1909	13.7	18.0	18.8
1910-1914	18.6	19.7	18.4
1915-1919	22.0	21.4	19.2
1920-1924	20.7	23.1	21.3
1925-1929	23.8	24.8	24.6
1930-1934	30.6	26.5	29.1

Three-year Sea-life Salmon. Three-year sea-life salmon form the main salmon supply of the Moisie River, averaging 58.8 per cent of the total catch. The weights of the scale-read salmon of this class range from 12 to 35 pounds and average 20.7 pounds.

Four-year Sea-life Salmon. The percentage, 0.5 per cent, of the salmon which return after four years in the sea for their first spawning is so small that this group, like the grilse, is of negligible importance in the classification of Moisie salmon.

Previously Spawned Salmon. The proportion of spawned salmon to the total stock (Table 1) is considerably higher in the Moisie River than that of the other salmon rivers of the Maritime Provinces, the Cascapedia River being the only one with a similarly high percentage. The annual variation over an eight-year period is marked, ranging from 11.9 to 39.6 per cent, and the mean is 22.3 per cent.

The 522 salmon which had previously spawned are arranged in Table 4 according to the number of previous spawnings. Three salmon returning to spawn for a fifth time were reported, one each, by Gilbert (Unpub.), Menzies (1926), and Macfarlane (1928). Their

TABLE 4. MULTIPLE SPAWNING, INTERVAL BETWEEN SPAWNINGS, AND SEA LIFE AT FIRST SPAWNING OF PREVIOUSLY SPAWNED SALMON

	Number	Per cent
A. Multiple spawning		
1 spawning mark	375	71.8
2 spawning marks	109	20.9
3 spawning marks	35	6.7
4 spawning marks	3	0.6
Total	522	100.0
B. Interval between first and second spawnings		
Short	13	3.5
Long	359	95.7
Very long	3	0.8
Total	375	100.0
C. Sea life at first spawning		
Two-year	51	13.0
Three-year	343	87.0
Total	394	100.0

ages were 13, 13, and 14 years. In two instances the weights were recorded, namely, 32 and 38.5 pounds. Practically all the salmon, 95.7 per cent, had an interval of at least one complete year in the sea (long period) between visits to the river for spawning purposes. Of 394 previously spawned salmon, 13 per cent had spawned for the first time after two years in the sea and 87 per cent after three years.

The proportion of salmon spawning for the first time after two years of sea life to the total previously spawned salmon is much lower than the proportion of 2-year sea-life salmon to the total stock. Likewise, if the number of 2-year sea-life salmon and older salmon is compared with the number returning to spawn a second time two years later, it will be found that the percentage of surviving 2-year sea-life fish is less than one-quarter that of the older salmon. Evidently the percentage of 2-year sea-life salmon which survive for a second spawning season is considerably less than that of the 3-year sea-life salmon.

The Salmon Stock of the Moisie River

In view of the apparent decline in the salmon of certain areas on the north shore of the St. Lawrence, it is of interest to know whether the Moisie River salmon are increasing, decreasing, or remaining constant in number. This problem may be studied from the standpoint of (1) the annual catch for the forty-year period from 1895 to 1934 inclusive, and (2) the rod catch per day for the thirty-three-year period from 1902 to 1934 inclusive. The former, while of interest, does not give as accurate a picture as the rod-day catch, since no allowance is made for the number of anglers or for fishing days, which vary considerably from year to year.

Cycles in Abundance. A cyclic phenomenon having a ten-year period, similar to that described for the Restigouche River by Phelps and Belding (1931), is also present in the Moisie catch. It is more definite in the 2-year sea-life salmon than in the older salmon, which show a more pronounced secondary peak at the second year of the decade. In order to eliminate the influence of this cyclic phenomenon the statistics of the total catch and rod-day catch have been grouped in five-year periods, each of which covers an equal half of the cycle.

Total Catch. Table 5 gives the average annual catch in five-year periods during the forty years from 1895 to 1934 for the total salmon, the 2-year sea-life salmon, and the combined 3-year sea-life, 4-year sea-life, and previously spawned salmon. The data indicate that there has been a steady rise from the 1895-1899 period to the 1925-1929 period with the exception of the 1915-1919 period during the World War, while the 1930-1934 period shows a decided falling off from the peak achieved in the previous five years.

TABLE 5. ANNUAL CATCH OF SALMON IN THE MOISIE RIVER, 1895-1934, BY FIVE-YEAR GROUPINGS PER 100,000 FOR TOTAL CATCH

Five-year period	Total salmon	2-year sea-life salmon	3-year sea-life, 4-year sea-life, spawned salmon
1895-1899	932	139	793
1900-1904	1,095	254	841
1905-1909	1,618	237	1,381
1910-1914	2,402	486	1,916
1915-1919	1,983	495	1,488
1920-1924	3,100	735	2,365
1925-1929	6,243	1,574	4,669
1930-1934	2,627	869	1,758
Mean	2,500	599	1,901

Rod-day Catch. Table 6 gives the actual rod-day catch and geometric trend for the 2-year sea-life salmon, the older salmon, and the total salmon. On the basis of the geometrical trend the maximum for the total salmon occurred in the 1920-1924 period, for the older salmon in the 1915-1919 period, and for the 2-year salmon in the 1925-1929 period. It is evident that there has been an increase in the rod-day catch up to 1920-1924 and that there has been a definite decline since that time. The decline started earlier and is somewhat more pronounced in the older salmon. The increase in the proportion of 2-year sea-life salmon, which show no evidence of a decline, has tended to offset the more marked decline in the larger fish.

TABLE 6. ROD-DAY CATCH IN THE MOISIE RIVER BY FIVE-YEAR GROUPINGS PER 1,000 SALMON FOR ROD-DAY TOTAL FROM 1902-1934

	Actual			Geometric trend		
Five-year period	Total salmon	2-year sea-life salmon	3-year sea-life, 4-year sea-life, spawned salmon	Total salmon	2-year sea-life salmon	3-year sea-life, 4-year sea-life, spawned salmon
1900-1904	24.98	6.07	18.91	21.12	4.30	16.82
1905-1909	24.79	3.67	21.12	27.19	5.63	21.56
1910-1914	34.02	7.02	27.00	31.30	6.64	24.66
1915-1919	29.91	7.27	22.64	33.51	7.40	26.11
1920-1924	32.06	7.40	24.66	33.83	7.97	25.86
1925-1929	37.56	9.61	27.95	32.18	8.22	23.96
1930-1934	26.62	8.09	18.53	28.58	8.22	20.36

Weight of Salmon

The weight of salmon varies from year to year, the same annual fluctuations occurring simultaneously in all the rivers of the Gulf of St. Lawrence. By the use of five-year periods in our calculations these fluctuations are minimized. In Table 7 the mean weights of the 2-year sea-life salmon, the older salmon, and the total salmon for seven five-year periods from 1900 to 1934 are given, the actual weights being compared with the straight line trend weights. The

TABLE 7. THE MEAN WEIGHTS OF MOISIE RIVER SALMON BY FIVE-YEAR PERIODS

Five-year period	Total salmon Mean actual weight	Total salmon Straight line trend	2-year sea-life salmon Mean actual weight	2-year sea-life salmon Straight line trend	3-year sea-life, 4-year sea-life, spawned salmon Mean actual weight	3-year sea-life, 4-year sea-life, spawned salmon Straight line trend
1900-1904	20.72	20.05	11.32	10.20	25.36	22.26
1905-1909	19.64	19.60	9.40	10.23	21.40	21.92
1910-1914	18.83	19.14	10.08	10.26	21.05	21.58
1915-1919	18.17	18.69	9.93	10.28	20.92	21.24
1920-1924	17.57	18.24	9.91	10.31	19.95	20.90
1925-1929	17.68	17.78	10.33	10.34	20.16	20.56
1930-1934	18.21	17.33	11.00	10.36	21.61	20.22
Mean of periods	18.69		10.28		21.24	

2-year salmon show a slight rise in weight; the older salmon show a progressive decrease in weight, which is reflected in the decreasing weight of the average salmon. The decreasing weight of the average salmon is further accentuated by the increasing proportion of 2-year sea-life salmon in the total catch.

It is of interest to see whether the loss in weight in the older salmon is due to the decline in number of the very large salmon. Table 8, which shows the percentage of salmon weighing 30 pounds and over to the old salmon, indicates a marked decrease in these very large fish. In the series of scale-read salmon only 3.7 per cent of the 3-year maiden salmon are 30 pounds or over, as compared with 45.7 per cent for the previously spawned salmon. Since the previously spawned salmon constitute about one-quarter of the combined 3-year sea-life and previously spawned salmon, the 3-year sea-life salmon furnish only about one-third of the very large salmon. The principal decline in these large salmon is, therefore, in the previously spawned salmon.

The Salmon Parr

Records as to length, weight, and river age were made on 238 parr. Table 9 gives the number and length of these parr arranged accord-

TABLE 8. THE DECREASE IN THE PERCENTAGE OF LARGE SALMON

Five-year period	Percentage of salmon 30 pounds and over to old salmon: Actual	Percentage of salmon 30 pounds and over to old salmon: Straight line trend
1900-1904	11.78	8.27
1905-1909	5.86	7.31
1910-1914	3.96	6.35
1915-1919	5.69	5.39
1920-1924	2.44	4.43
1925-1929	2.33	3.47
1930-1934	5.68	2.51
Mean	5.39	5.39

ing to river years. The 1931 collection was taken on August 1, the 0+ parr by day seining and the older parr by rod. The 1934 collection was taken on September 1 by night seining. The season of growth is relatively short in the Moisie River. Hatching does not take place until after May 15, and there is little increase in length after September 1. The average temperature in the Moisie River for the five years from 1931 to 1935 during the summer period of growth was: the last half of May 41.7° F., June 52.5° F., July 61.5° F., and August 61.0° F.

TABLE 9. NUMBER, AGE GROUPS, AND LENGTH OF MOISIE RIVER PARR

River years	1931 collection			1934 collection		
	Number of parr	Length (millimeters) Total	Length (millimeters) Mid-tail	Number of parr	Length (millimeters) Total	Length (millimeters) Mid-tail
0+	17	37.5	35.5	113	41.5	38.8
1+	27	66.9	62.3	53	73.5	68.1
2+	5	104.4	96.2	10	102.5	94.6
3+	11	121.6	111.7	2	125.0	115.5

Length of Parr. The figures in Table 10 have been compiled from actual and calculated lengths. The fast-growing parr leave as 3-year smolts and the slow-growing as 4-year smolts. The calculated lengths indicate that the rate of growth of the 4-year smolt is consistently slower at each year of life than that of the 3-year smolt. The mean lengths of the average parr for one, two, and three years of river life may be determined, but inasmuch as the larger parr leave as 3-year smolts it is impossible to give comparable figures for the 4-year old parr.

The Moisie River parr differ from the parr of other rivers, where the annual rate of growth is approximately the same, in that the first year's growth is unusually slow. Evidently the food supply of the small parr in the lower Moisie River is poor, or a late hatch and a prolonged yolk sac stage have shortened the period of active growth.

TABLE 10. LENGTH OF THE MOISIE RIVER PARR

River years	Total length (millimeters)			Mid-tail length (millimeters)		
	3-year smolt	4-year smolt	Average	3-year smolt	4-year smolt	Average
1	42	39	41	40	37	39
2	74	68	72	69	63	67
3	106	97	103	98	89	95
4	....	126	....	....	115	....
Smolt	117	137	....	108	125	....
Average annual gain	32	29	31	29	26	28

Actual vs. Calculated Length. The calculated lengths of the parr are less than the actual lengths (Table 11), in contrast with other rivers where the calculated lengths usually agree closely with the actual lengths. The lengths as calculated from the adult salmon scales are more nearly similar to the actual length of the parr. The size of the first-year parr, as calculated from the adult scale, is relatively large, possibly owing to the difficulty of judging accurately the starting point for the scale measurement.

TABLE 11. ACTUAL VS. CALCULATED LENGTH OF THE MOISIE RIVER PARR

River years	Parr				Adult	
	Total length		Mid-tail length		Total length calculated	Mid-tail length calculated
	Actual	Calculated	Actual	Calculated		
1	42	40	40	38	44	42
2	74	70	69	65	74	68
3	107	100	99	92	105	96

Equation for Parr Growth. The growth of the scale corresponds in general to the growth of the parr, but the relation between the length of the parr and the size of the scale varies with the rapidity of growth, the slow-growing parr having a relatively larger scale than the fast-growing parr. Therefore, the ratio of the length of the parr and the size of the scale varies in different rivers and may be expressed for each river mathematically. The equation for the total length (L) and scale (S) in the Moisie River parr is $S = 0.0502\ L - 1.035$.

Smolt Length. Most of the smolt probably leave the river in June. About two-thirds leave at the beginning of their fourth year and one-third at the beginning of their fifth year. The short additional period of growth in the spring before leaving the river makes the length of the smolt somewhat greater than that of the parr in the previous fall.

Weight. The weight in grams of the Moisie parr of average length at 1, 2, 3, and 4 years is given in Table 12. The weight of the

TABLE 12. TOTAL LENGTH, WEIGHT, AND COEFFICIENT OF CONDITION OF MOISIE RIVER PARR

River years	Number	Length (millimeters)		Weight, grams	Coefficient of condition	
		Total	Mid-tail		Total length	Mid-tail length
0+	130	40.98	38.39	0.58	0.836	1.017
1+	80	71.24	66.13	3.09	0.856	1.070
2+	15	103.13	95.13	9.85	0.898	1.145
3+	13	122.15	112.31	15.61	0.856	1.103

1-year parr is considerably less than that of the same sized parr in other rivers, while that of the older parr is only slightly lower.

Coefficient of Condition. The coefficient of condition, determined by dividing 100 times the weight in grams by the cube of the length in centimeters, provides an index of the growth of parr with respect to environment, and may also indicate differences in anatomical structure between parr of different rivers. Table 12 shows that the coefficient of condition increases slightly with the age of the parr. The coefficient of condition of the Moisie River parr is below the average of that of the parr of the salmon rivers of the Bay of Chaleur.

Summary

1. The proportion of the several classes of adult salmon in the Moisie River for the years 1919 to 1927 is: 1-year sea-life 0.04 per cent, 2-year sea-life 18.31 per cent, 3-year sea-life 58.84 per cent, 4-year sea-life 0.51 per cent, and previously spawned salmon 22.30 per cent.

2. The annual percentage of 2-year sea-life salmon fluctuates from 7.7 to 51.3 per cent and follows a five-year cycle, the peak years corresponding to the zero and five years of the decade.

3. The percentage of previously spawned salmon, 22.3 per cent, is extremely high for Canadian rivers, and the large number returning for multiple spawnings is unusual. Practically all the multiple spawning salmon, 95.7 per cent, remain one year in the sea between spawnings. About 87 per cent of the previously spawned salmon spawned for the first time after three years in the sea.

4. A ten-year cyclic phenomenon in the abundance of salmon, with its peak at the five years of the decade, is present.

5. An analysis of the rod-day and the annual catch indicates that the stock of salmon reached its peak in the five-year period from 1920 to 1924 and since that time has declined. This decline has been confined wholly to the 3-year sea-life and previously spawned salmon, while the 2-year sea-life salmon have shown a steady increase except for the 1930-34 period.

6. There has been a progressive reduction in the average weight of the Moisie River salmon. This loss has occurred in the 3-year sea-life and previously spawned salmon, the 2-year sea-life salmon showing no loss in weight. The loss of weight in the older salmon is chiefly the result of a decline in the number of salmon 30 pounds and over, three-quarters of which are previously spawned salmon. The more marked loss of weight in the average Moisie River salmon is due in part to the increased proportion of the small 2-year sea-life salmon.

7. The rate of growth of the Moisie River parr is slower than that of the parr of the large rivers of the south and west shores of the

Gulf of St. Lawrence. The mean total lengths for the several year classes are: 1-year parr 41 millimeters, 2-year parr 72 millimeters, and 3-year parr 103 millimeters.

8. The weight and coefficient of condition of the Moisie River parr are lower than those of the parr of similar ages and lengths in the large rivers of the south and west shores of the Gulf of St. Lawrence.

9. About two-thirds of the smolt leave the Moisie River at the beginning of the fourth year and one-third at the beginning of the fifth year.

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LOSS OF WEIGHT BY RAINBOW TROUT AT SPAWNING TIME[1]

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It is a well-known fact among fish culturists that the various species of salmon and trout feed only intermittently just before spawning and may cease feeding altogether during the spawning activities. The final elaboration of the sexual products and the energy required for migration to the breeding grounds and subsequent activities must therefore draw extensively on stored body materials. A good opportunity for studying this problem was afforded in 1935 at Paul Lake, British Columbia, where a single population of rainbow trout enters the creek to spawn.

The Biological Board of Canada maintained a counting fence at the mouth of Paul Creek from 1932 to 1936, inclusive. Here each fish was counted, the sex noted, and scale samples for age determinations collected before it was allowed to proceed upstream to the spawning grounds. In 1935, about 1,300 of the upstream migrants were tagged with serially numbered tags, and each fish was weighed to the nearest tenth of a pound. As the fish returned to the lake after spawning, 383 of the tagged fish, 103 males and 280 females, were taken at random and weighed. An exact record of the loss of weight by each fish was thus obtained.

Since the actual loss of weight was found to vary with the size of the fish, it was necessary to work out a method of comparing the loss by individuals. Consequently, the data for 140 3-year-old females ranging in size from 1.2 to 3.2 pounds were segregated, and the loss by each fish was calculated as a percentage of the weight recorded before spawning. These data when plotted showed that the percentage loss by large and small fish of the same age and degree of maturity (spawning for the first time) was approximately the same, and that there was no significant trend in the slope of the curve. Thus it was assumed that the ratio of percentage loss could be used for comparing the loss of weight by different fish, regardless of their size.

Accordingly, the percentage loss of weight of the 383 fish in the sample was calculated (Table 1). The average percentage loss of weight was found to be 16.7 per cent by the males and 25.2 per cent by the females.

The total loss may be ascribed to two main causes: the shedding of the reproductive products, and the utilization of stored materials to produce the energy needed during the spawning activities. In or-

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TABLE 1. NUMBER AND PERCENTAGE OF MALE AND FEMALE RAINBOW TROUT IN THE VARIOUS PERCENTAGE-LOSS-OF-WEIGHT CATEGORIES

Percentage loss	Males Number	Males Per cent	Females Number	Females Per cent
1- 5	3	2.9	2	0.7
6-10	20	19.4	8	2.9
11-15	18	17.5	18	6.4
16-20	37	36.0	36	12.8
21-25	14	13.6	83	29.6
26-30	6	5.8	68	24.3
31-35	3	2.9	48	17.1
36-40	1	1.0	13	4.6
41-45	1	1.0	4	1.4
Total number	103		280	

der to determine the relative amount of the loss due to each of these factors, the gonads of a number of fish were weighed before spawning. In seventeen females averaging 2.0 pounds in weight and carrying, on the average, about 2,500 eggs, the ovaries made up 19 per cent of the total body weight. In fifty males the gonads made up, on the average, about 5 per cent of the total body weight.

It is clear that only part of the eggs or milt may be shed during spawning, and a variable amount of material may be left in the body cavity. In a sample of ten females, taken when they were migrating back to the lake, the average number of eggs was found to be 181, but the number varied from 0 to 1,192. The weight of the unshed eggs, together with the ovarian membranes, was estimated to be about 3 per cent of the total body weight before spawning. In the males, where the gonads only made up 5 per cent of the total body weight, it was estimated that the total amount of material shed during spawning was about 2 per cent of the original body weight. From these figures it was calculated that the amount of material lost through the shedding of the reproductive products was 16 per cent in the females and 2 per cent in the males.

Since the average percentage loss by the males amounted to 16.7 per cent, and that by the females 25.2 per cent, a loss of about 9 per cent in the females and 14 per cent in the males still remains to be accounted for. This loss may be attributed to the utilization of materials to produce energy during spawning.

Since the average length of time spent in the creek by these fish was 28.4 days for males, and 26.5 days for females, the average loss per day due to energy expenditure was calculated as 0.49 per cent of the total body weight before spawning for the males and 0.34 per cent for the females. These figures were checked in another way. In order to eliminate the factors of size, age, and degree of maturity, and thus obtain a more homogeneous sample, sixty-five of the 3-year-old females, ranging in weight from 2.0 to 2.5 pounds, were grouped according to the length of time spent in the creek.

The average percentage loss of weight was as follows: those spending three weeks lost 26 per cent, those spending four weeks lost 28 per cent, those spending five weeks lost 30 per cent, and those spending six weeks lost 32 per cent. This series shows a progressive loss of 2 per cent per week, or approximately 0.3 per cent per day. The 3-year-old males, when classified in a similar manner, showed a loss of 3.8 per cent per week, or approximately 0.5 per cent per day. It is evident from these data that the males lost a significantly greater amount of their weight due to the expenditure of energy than did the females.

The number of times that the fish had spawned seemed to have an effect on the loss of weight. In Table 2 the data for the percentage loss of weight of fish of different ages were arranged according to the number of times that they had spawned as determined by the spawning marks on the scales. Those spawning for the first time were placed in one group, and those spawning for the second, third, or fourth time were placed in another group.

TABLE 2. PERCENTAGE LOSS OF WEIGHT BY MALE AND FEMALE RAINBOW TROUT OF DIFFERENT AGES

Age	First spawners	Total number	Second, third or fourth spawners	Total number
		Females		
III	27.6	140	----	----
IV	26.2	54	22.0	51
V	----	----	20.1	20
VI	----	----	15.0	6
Average	27.2		21.0	
		Males		
II	19.2	19	----	----
III	16.5	42	16.2	10
IV	16.8	10	14.5	15
V	----	----	15.5	6
Average	17.3		15.2	

The difference between the percentages for the 4-year-old females was treated statistically and found to be significant. However, the difference between the 3 and 4-year-old males taken together, was not statistically significant. Taking all the age-groups together, there is sufficient evidence to conclude that fish spawning for the first time lose a significantly greater percentage of their weight than do those spawning more than once.

It is obvious that spawning in rainbow trout places a great drain on the body reserves. At the beginning of the Paul Lake investigations in 1931, a number of fish were weighed and tagged. Those recaptured in subsequent years made practically no gain in weight. In one instance a female, tagged going downstream in 1931, weighed 3.2 pounds; it was weighed going upstream to spawn in 1935, four

years later, when it was 3.7 pounds. There is a common belief among anglers that wild rainbow trout continue to grow indefinitely after spawning, but this is apparently not the case. Once the trout reach maturity and spawn, a considerable amount of food is required to make up for the material lost, to renew the reproductive products, and to supply the energy for the next spawning migration. Unless the food supply is very rich, there is only a slight gain in weight from year to year after the fish become mature adults. In the majority of lakes the size ultimately attained by rainbow trout appears to depend on the rate of growth in the first few years before maturity is reached, and this in turn is dependent on the abundance of food. However, in lakes where large quantities of forage fish are available, the trout may continue to grow after reaching maturity.

The values obtained for the percentage loss per day by male and female trout may prove useful to fish culturists who are studying the conversion of various foods. The difference between the males and females indicates the necessity for taking the activity of the fish into account in food conversion studies. The males are extremely active at spawning time, and expend a good deal of energy in fighting off other males and maintaining a spawning position. In this particular year (1935) there was an excess of small males competing for the spawning positions and the loss values obtained may be high. It is probable that the type of pond or race-way used in food studies, and the difference in separate strains of fish with regard to wildness, may seriously affect the results.

ADDITIONAL RETURNS FROM FISH TAGGED IN OHIO

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In 1930 the Ohio Division of Conservation started a program of tagging fish and these operations have been continued since that year. The results for 1930, 1931, and 1932 were reported to this Society in 1933. These data showed 2.2 per cent returns from 4,954 wild fish, representing eleven species live-trapped at Buckeye Lake during the summer of 1930. In 1931 and 1932, 3,005 adult wild fish from Lake Erie were tagged and released in the streams of Ohio, with returns of 1.3 per cent. Our records showed a definite downstream movement. One adult smallmouth bass travelled over 200 miles with the current of the Great Miami and Ohio rivers in 217 days, and another adult smallmouth moved 135 miles downstream in the Walhonding, Muskingum, and Ohio rivers at an average speed of 13.5 miles per day for 10 days.

The 106 stream returns showed that 37 per cent of the fish moved 10 miles or less; 20 per cent, 11 to 25 miles downstream; 26 per cent, 26 to 50 miles downstream; 12 per cent, 51 to 100 miles downstream; and 5 per cent 100 to 205 miles with the current. In other words, 83 per cent travelled up to 50 miles and 17 per cent from 51 to 205 miles. The fish taken by fishermen included thirty-five smallmouth bass, twenty-eight channel catfish, twenty-five rock bass, fourteen bullhead catfish, three largemouth bass and one carp.

Thirty-one of the thirty-nine fish recaptured within 10 miles moved 5 miles or less. The average fish was caught sixty-two days after its release. The shortest period of release was less than a day and the longest 263 days. The shortest time of release for the twenty-one fish moving 11 to 25 miles was 9 days and the longest was 387 days. The shortest time between releasing and catching the twenty-eight fish moving from 26 to 50 miles was five days for a distance of 35 miles and at the rate of 7 miles per day. The longest time was 246 days for 45 miles.

For the thirteen fish moving 51 to 100 miles the shortest time of release was thirty days for 88 miles at an average speed of 2.9 miles per day. The longest time was 242 days for 55 miles at an average speed of 0.23 mile per day.

Of the five fish going over 100 miles the shortest time was ten days for 135 miles or 13.5 miles per day. The longest time was 217 days for 140 miles for an average speed of 0.64 mile per day.

One fish was caught in January; three in February; four in March; fifteen in April; twenty-four in May; twenty in June; eight in July; two in August, none in September; six in October; twenty-one in November, and two in December.

DOES THE FULL MOON AFFECT RAINBOW TROUT FISHING?

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Since the fishery administrator is dependent to a great extent on the reports of anglers as to the condition of the sport fisheries under his jurisdiction he should be in a position to discriminate between reports of genuine depletion and "fishermen's alibis." In recent years the fishing alibi has taken an astronomical trend and many theories have been formulated and placed before the angling public. One of these theories is that the fishing is adversely affected at the time of the full moon. If this is correct then any report based on the results obtained from fishing during the period when the moon is full may give a false idea of the state of the fishery. The main purpose of the present paper is to show the general method of investigating such problems.

No doubt the belief that the moon has an effect on the fishing has been borrowed from marine fishermen. In the sea, however, the situation may be related to the effect of the tides, which are definitely associated with the phases of the moon. In fresh water, no such explanation is possible. The idea that the moon affected the fishing first became general at Paul Lake in 1935. Since a record of the anglers' catches or creel census was kept from 1932 through 1936 in which over 27,000 rainbow trout were counted, representing about two-thirds of the total catch, it was not a difficult matter to test the hypothesis.

An index of the success of the fishing may be stated in terms of the catch per unit effort. Fishing at Paul Lake is carried on entirely from boats by fly fishing and trolling, so the number of fish caught per boat per day was used as an index of the success of the fishing. Other investigators employing the creel census method usually state their results in terms of the number of fish caught per fisherman per hour. In order to convert the values given here into terms of fish per fisherman per hour the indices should be divided by ten because the "boat-day" was found to represent, on the average, the effort of two fishermen fishing for five hours.

In order to test the effect of the full moon on the fishing the full moon period was taken as the two days before, the day of, and the day after the calendar date of the full moon, thus making four days in all. The average catch per boat per day for the six months of the fishing season from 1932 through 1936 and the corresponding catch for the full moon periods is shown in Table 1. The weighted average catch for the thirty months taken together was 7.69 fish per boat per day, whereas the weighted average catch for the thirty full moon periods was 7.58 fish per boat per day. It is apparent from

these data that the average yield of rainbow trout to the fishermen was not decreased very much at the time of the full moon. The table shows, however, that there was considerable variation in some months, particularly in 1934, which might easily have given credence to the theory that the full moon affects the fishing.

TABLE 1. AVERAGE CATCH PER BOAT PER DAY (M) FOR THE SIX MONTHS OF THE FISHING SEASON AT PAUL LAKE FROM 1932 THROUGH 1936 AND THE CORRESPONDING AVERAGE FOR THE FOUR DAYS AT THE TIME OF THE FULL MOON (FM) IN EACH MONTH. THE AVERAGE MONTHLY CATCH PER BOAT PER DAY FOR ALL YEARS IS GIVEN IN THE LAST COLUMN.

Month	1932		1933		1934		1935		1936		1932-1936 Average
	M	FM	M	FM	M	FM	M	FM	M	FM	M
May	3.5	4.1	6.3	7.0	7.5	5.0	12.7	13.9	8.3	5.5	7.66
June	2.2	2.6	5.2	5.8	5.4	4.4	10.1	9.7	7.4	11.1	6.06
July	3.9	5.3	3.4	2.5	4.7	2.8	7.4	5.9	5.8	5.4	5.04
August	4.9	3.3	6.0	3.5	6.8	6.0	6.6	4.4	6.2	5.2	6.10
September	6.2	7.0	7.5	9.5	11.4	10.0	10.2	5.7	13.7	10.1	9.80
October	6.9	9.7	8.1	8.3	13.6	12.0	11.9	13.5	13.3	13.9	10.80

TABLE 2. DIFFERENCE BETWEEN THE AVERAGE CATCH PER BOAT PER DAY FOR EACH MONTH AND THE AVERAGE CATCH PER BOAT PER DAY FOR THE FULL MOON PERIOD. THE VALUE OF THE STATISTIC t CALCULATED FROM THE AVERAGE DIFFERENCES IS SHOWN IN THE LAST COLUMN AND THE LAST ROW.

Month	1932	1933	1934	1935	1936	Average difference	t
May	+0.6	+0.7	—2.5	+1.2	—2.8	—0.56	0.651
June	+0.4	+0.6	—1.0	—0.4	+3.7	+0.66	0.812
July	+1.4	—0.9	—1.9	—1.5	—0.4	—0.66	1.15
August	—1.6	—2.5	—0.8	—2.2	—1.0	—1.62	4.92
September	+0.8	+2.0	—1.4	—4.5	—3.6	—1.34	1.08
October	+2.8	+0.2	—1.6	+1.6	+0.6	+0.72	1.34
Average difference	+0.73	+0.02	—1.53	—0.97	—0.58		
t	1.25	0.0318	6.05	1.04	0.547		

In order to determine the significance of these variations the difference between the average for each month and the corresponding full moon period was obtained and these data are shown in Table 2. To test the significance of these differences the statistic t (Fisher, 1936) was calculated for the various years and months. This statistic is appropriate to determine whether the average differences of such series as those given in the table vary significantly from zero. When t for any year exceeds 4.032 or when it exceeds 4.604 for any month, in this particular case, the average difference for that year or month may be considered significant. If the difference is in a negative direction then it may be concluded that the data show that the full moon does affect adversely the fishing.

The values of t show that there was a significant reduction in

the catch during the full moon in 1934 and a consistent reduction in the catch for the month of August in the several years. Based on the experience of 1934 the anglers were justified in formulating the theory that the full moon affects rainbow trout fishing. Likewise, if an angler, who subscribed to the theory that the full moon affects the fishing, had fished only during the month of August each year, he would have had a good alibi for smaller catches at the time of the full moon.

The effect of the moon on the fishing is obviously not a factor that operates continuously because it appears in some years and not in others. A factor such as the light reflected by the moon which may be rendered non-operative at times by cloudy weather seems to be involved. Anglers often report that trout may be caught all night long on a bright moonlight night. It seems reasonable that when fish feed at night they may have a tendency to feed less than usual during the day, which in turn may affect the catch. Since surface-feeding fish would be affected to a greater extent by this condition it may have an important effect on the success of fly-fishing which depends almost entirely on the presence of feeding fish near the surface.

From the foregoing data it may be concluded that some factor associated with the occurrence of the full moon does affect rainbow trout fishing. The factor does not operate at every full moon but the evidence suggests that bright moonlight nights may be responsible for a reduction in the catch at certain times.

I am indebted to Mr. W. Nation, guide at Paul Lake, for actual observations on the effect of the full moon on the fishing and to the Biological Board of Canada for permission to publish the data. Dr. J. L. Hart, of Nanaimo, has kindly assisted in a critical examination of the statistical methods.

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THE FOOD OF NINE SPECIES OF FISH FROM THE WESTERN END OF LAKE ERIE

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The present study is one of a series that resulted from the Lake Erie Cooperative Hydrobiological Survey of 1926-1930. This survey covered detailed ichthyological and limnological investigations of the western end of Lake Erie undertaken jointly by the Ohio Conservation Division, the Franz Theodore Stone Laboratory, and the U. S. Bureau of Fisheries. The main report is in manuscript form ready for publication. All species of fish included in the present paper feed to an important extent on insects. Those species feeding largely on crustaceans were considered in a paper published by Ewers (1933). The purpose of the study has been to determine as specifically as possible the nature of the food of the various fishes. The writer is much indebted to Mr. E. L. Wickliff of the Bureau of Fish Management and Propagation of the Ohio Conservation Division for all the specimens and many valuable suggestions; to Dr. Lela A. Ewers for the identification of the Crustacea mentioned in the report; and to Dr. R. C. Osburn for research facilities at the Franz Theodore Stone Laboratory.

The method of procedure in securing the data for each specimen was as follows. The digestive tract of the fish was removed and the stomach contents were carefully isolated in a small dish. The various types of food materials were then sorted into separate dishes and identified as far as the condition of the material would permit. The percentage of total volume of each type of food organism was carefully estimated. Stomach contents always include everything except animals known to be parasitic in the fish. Debris recorded in the tables includes material that may have been picked up incidentally by the fish in feeding and also material digested beyond the point of recognition as definite organisms. That in some species the stomach contents were invariably well digested may have been due to the fact that the regular feeding time was far removed from the time of capture.

Mooneye (*Hiodon tergisus*)

Specimens were taken at six seining stations (Tables 1 and 2). At three stations the bottom was sandy, either without vegetation or with some *Potamogeton* and *Scirpus*. At two stations it was hard clay with some mud, *Potamogeton* extending far out into the lake. The four specimens which were not over 39 millimeters long fed on Entomostraca, whereas those not less than 57 millimeters long fed entirely on insects and amphipods. The older fish had taken their food largely from the surface of the water. Most of the insects

eaten had probably fallen into the water but some were apparently caught in the act of emerging or in preparation for emergence. While most of the food of specimens ranging from 57 to 133 millimeters in length consisted of insects from the surface, there were also some mayfly naiads (*Hexagenia*), midge larvae, and caddice-worms. The great variety of insects taken is clearly indicated in Table 2. Forbes (1888) found the food of five specimens to consist "wholly of insects (two-thirds of them terrestrial) with the excep-

TABLE 1. STOMACH CONTENTS OF SEVEN MOONEYES (*HIODON TERGISUS*) TAKEN AT VARIOUS POINTS IN WESTERN LAKE ERIE, JUNE 27 TO JULY 23, 1929. TOTAL LENGTH, 25 to 80 MILLIMETERS; AVERAGE LENGTH, 46.25 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	3	42.9	28.6	0.9	4
Chironomidae, pupae (*Chironomus*, etc.)	2	28.6	17.9	0.6	3
Chironomidae, adults	1	14.3	7.1	0.1	....
Formicidae, adults	1	14.3	3.6	0.1	1
Cladocera (*Daphnia retrocurva*)	4	57.1	42.9	1.3	4
Debris	3	42.9	28.6	....	....

TABLE 2. STOMACH CONTENTS OF NINE MOONEYES (*HIODON TERGISUS*) TAKEN IN SEINE AT CEDAR POINT ON SEPTEMBER 7, 1929. TOTAL LENGTH, 87 TO 133 MILLIMETERS; AVERAGE LENGTH, 102.3 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	9	100.0	99.4	19.1	48
Ephemerida, naiads (*Hexagenia*)	8	88.9	31.8	8.1	35
Odonata (Coenagrionidae), adults	1	11.1	0.1	0.1	....
Homoptera (Cicadellidae, Aphididae)	5	55.6	2.2	1.0	3
Hemiptera (Nabidae, etc.)	7	77.8	6.6	0.8	1
Coleoptera, adults (Chrysomelidae, Carabidae, Rhynchophora)	6	66.7	7.4	0.8	2
Trichoptera, larvae	2	22.2	0.2	0.2	....
Trichoptera, pupae	3	33.3	2.6	0.3	....
Lepidoptera, pupae	1	11.1	3.1	0.1	1
Lepidoptera, adults	1	11.1	0.6	0.1	....
Diptera	8	88.9	16.6	6.4	15
Tipulidae, adults	1	11.1	0.3	0.1	....
Chironomidae, larvae	1	11.1	0.1	0.1	1
Chironomidae, pupae	4	44.4	5.9	2.1	12
Chironomidae, adults	4	44.4	5.4	2.5	15
Mycetophilidae, adults	2	22.2	0.2	0.2	....
Dolichopodidae, adults	4	44.4	1.7	0.4	....
Phoridae, adults	1	11.1	0.1	0.1	....
Acalyptratae, adults	6	66.7	2.7	0.8	3
Hymenoptera, adults (Braconidae, Ichneumonidae, Formicidae)	4	44.4	3.8	0.7	3
Crustacea (Amphipoda)	1	11.1	0.6	0.1	....

tion of a trace of univalve Mollusca." He gave the length of one of the fish as 2⅞ inches. Sibley (1929) found some Cladocera (6 per cent) in 106- to 146-millimeter specimens, but terrestrial insects comprised the most abundant food.

Silver Chub (*Hybopsis storerianus*)

Specimens were taken at six western Lake Erie stations (Table 3). Entomostraca were found only in fish of 88 millimeters or less in length. However, one specimen as small as 65 millimeters was found to have eaten nothing but insects. The occurrence of an amphipod in a 106-millimeter specimen is in agreement with our findings which indicate that insect-eating fish may be expected to feed on amphipods even though they take no entomostracans. The bulk of the material in the stomachs was debris. Over 40 per cent of the total contents (including debris) consisted of insects, principally midge larvae and water-boatmen; the remainder consisted of Cladocera (*Daphnia*) and Amphipoda (*Gammarus*), with a trace of mollusk remains. The results in general agree very well with those of Sibley (1929), who found that 90- to 110-millimeter specimens took midge larvae (77 per cent), corixids, miscellaneous insects, and snails.

TABLE 3. STOMACH CONTENTS OF THIRTEEN SILVER CHUBS (*HYBOPSIS STORERIANUS*) TAKEN AT VARIOUS WESTERN LAKE ERIE STATIONS, JUNE 25 TO SEPTEMBER 8, 1929. TOTAL LENGTH, 62.5 TO 126 MILLIMETERS; AVERAGE LENGTH, 86.8 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	11	84.6	40.4	7.7	35
Ephemerida, naiads (*Hexagenia?*)	2	15.4	4.2	0.2	1
Hemiptera (Corixidae)	3	23.1	16.5	0.5	3
Trichoptera, larvae	1	7.7	5.4	0.1	1
Trichoptera, pupae	1	7.7	1.1	0.1	1
Chironomidae, larvae	7	53.8	9.3	6.8	34
Chironomidae, adults (*Cricotopus*)	1	7.7	3.8	0.1	1
Crustacea	4	30.8	3.9	0.8	8
Cladocera (*Daphnia retrocurva*, etc.)	3	23.1	3.8	0.7	8
Amphipoda (*Gammarus*)	1	7.7	0.1	0.1	1
Pelecypoda	1	7.7	----	----	trace
Debris	12	92.3	55.7	----	----

Common Sunfish (*Eupomotis gibbosus*)

One Lake Erie specimen, 119 millimeters in total length, had the following stomach contents: 15 mayfly subimagos (*Coloburus?*), 1 caddice-worm, some plant fragments, and debris. Volume estimates are as follows: mayfly subimagos, 96 per cent; caddice-worm, 1 per cent; plant fragments, trace; debris, 2 per cent. In the recent Buckeye Lake studies (Ewers and Boesel, 1935), 24- to 32-millimeter sunfish were found to feed predominantly on cladocerans and amphipods, with midge larvae making up over 10 per cent of the diet.

Redhorse Sucker (*Moxostoma aureolum*)

The stomach of one Lake Erie specimen, 96 millimeters in total length, taken on June 25, 1929 contained the following: 12 mayfly naiads, 20 per cent; 1 fragmentary Odonata naiad, 2 per cent; remains of 3 caddice-worms, 2 per cent; 43 midge larvae, 12 per cent; over 1,200 cladocerans (*Chydorus sphaericus, Bosmina longirostris, Alona quadrangularis,* and *Eurycercus lamellatus*), 55 per cent; 1 *Gammarus,* 1 per cent; and debris, 8 per cent.

Brook Silversides (*Labidesthes sicculus*)

Tables 4 and 5 summarize the food of specimens of two distinct size ranges. Fish that averaged 35.9 millimeters in length fed chiefly on Entomostraca, mainly copepods such as *Epischura lacustris* and *Cyclops prasinus,* whereas those individuals that averaged 61.2 millimeters fed predominantly on insects, particularly adult midges.

A series of twelve specimens (36 to 68 millimeters, total length) taken one-half mile east of Huron light showed a definite gradation in feeding habits. The smallest fish fed almost entirely on a variety of copepods, although a trace of an insect was present. Four specimens from 41 to 47 millimeters in length ate more insects than copepods from the standpoint of volume but from the standpoint of number of specimens insects were relatively insignificant. In one fish over 900 copepods constituted 100 per cent of the contents. Specimens from 51 to 68 millimeters in length showed a marked preference for insects as is indicated by the fact that only one individual out of seven had taken any Entomostraca. A 43-millimeter fish had eaten a spider, and a 68-millimeter one had eaten a fish.

The larger fish evidently do considerable feeding at the surface. In a series of three 51- to 62-millimeter fish taken at Cedar Point 100 per cent of the food consisted of adult insects that were probably caught after they had fallen on the surface of the water; adult midges were most numerous. In a 16- to 32-millimeter group, 100 per cent of the food consisted of Entomostraca, principally *Bosmina longirostris.* It seems, then, that in general the brook silversides first feed on Entomostraca and then shift over to insects, especially terrestrial forms.

No single species of Entomostraca was most commonly taken in two different habitats, a fact which may seem to indicate that the fish probably take the species that are most readily available. However, the fact that smaller individuals tend to take Entomostraca whereas larger ones in the same habitat take insects argues against the notion that the food consumed is determined entirely on the basis of availability.

Forbes and Richardson (1920) mention midge larvae as a prominent article of diet, but our Lake Erie specimens seem to have taken not a single one. However, one midge larva was found in a Buckeye

TABLE 4. STOMACH CONTENTS OF SEVENTEEN BROOK SILVERSIDES (*LABIDESTHES SICCULUS*) TAKEN AT FOUR WESTERN LAKE ERIE STATIONS, JULY 22 TO SEPTEMBER 7, 1929. TOTAL LENGTH, 16 TO 47 MILLIMETERS; AVERAGE LENGTH, 35.9 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	5	29.4	18.1	1.3	7
Chironomidae, pupae	2	11.8	4.4	0.3	5
Chironomidae, adults (*Procladius*, etc.)	4	23.5	9.9	0.8	7
Ceratopogonidae, pupae	1	5.9	0.8	0.1	1
Ephydridae, adults	1	5.9	2.9	0.1	1
Crustacea	17	100.0	81.5	106.5	900
Cladocera (*Bosmina, Chydorus, Daphnia, Diaphanosoma, Graptoleberis, Scapholeberis, Sida*)	8	47.1	29.7	14.9	75
Copepoda (*Cyclops, Diaptomus, Epischura*)	16	94.1	51.8	91.7	900
Araneida	1	5.9	0.5	0.1	1

TABLE 5. STOMACH CONTENTS OF FIFTEEN BROOK SILVERSIDES (*LABIDESTHES SICCULUS*) TAKEN AT THREE WESTERN LAKE ERIE STATIONS, SEPTEMBER 6 AND 7, 1928 AND 1929. TOTAL LENGTH, 51 TO 72 MILLIMETERS; AVERAGE LENGTH, 61.2 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	15	100.0	73.3	6.3	18
Homoptera (Cicadellidae, Cercopidae)	4	26.7	4.7	0.4	3
Psychodidae, pupae	1	6.7	0.5	0.1	2
Psychodidae, adults	1	6.7	0.2	0.1	1
Chironomidae, pupae	3	20.0	3.4	0.5	5
Chironomidae, adults (*Chironomus, Corynoneura, Cricotopus, Tanytarsus, Procladius*)	15	100.0	58.7	4.7	16
Ceratopogonidae, adults	1	6.7	0.7	0.1	1
Dolichopodidae, adults	1	6.7	0.9	0.1	1
Phoridae, adults	1	6.7	0.9	0.1	1
Ephydridae, adults	2	13.3	2.9	0.1	1
Crustacea	5	33.3	19.5	43.7	195
Cladocera (*Daphnia, Diaphanosoma, Leptodora*)	5	33.3	12.0	32.3	162
Copepoda (*Cyclops, Diaptomus, Epischura*)	5	33.3	7.5	11.5	66
Pisces	1	6.7	6.3	0.1	2
Debris	2	13.3	0.8	....	....

Lake specimen (Ewers and Boesel, 1935). Pearse (1915) found some plant material (algae, etc.) in specimens from Wisconsin, but insects, chiefly adults, were the most abundant group represented. Pearse (1918) found 44.6 per cent adult insects and pupae and 40.7 per cent entomostracans in fish that ranged from 11.5 to 77 millimeters

in length. In 19- to 35-millimeter fish, Sibley (1929) found about 50 per cent of the food to consist of Cladocera; next in abundance was the copepod *Leptocyclops agilis;* and surface insects were also represented.

Channel Catfish (*Ictalurus punctatus*)

The following is a summary of stomach contents expressed in per cent and arranged according to seining stations. Minor items are omitted. Station 1: insects (aquatic stages), 81.5; crustaceans, 10.5. Station 2: entomostracans, 92.5. Station 3: insects, 12.1; crustaceans, 78.4. Station 4: insects, 68.8; crustaceans, 12.7; debris, 13.2. Station 5: insects, 93.6. Station 6: insects, 69.7; fish eggs, 14.0. Station 7: insects, 53.6; debris, 31.8. Fish taken at the first five stations were all under 70 millimeters in length; those taken at the last two stations were all over 70 millimeters in length. A comparison of these summaries suggests either that the channel catfish does not have a constant diet or that the species has different food habits in different localities. It is probably not to any extent a selective feeder. It is true, however, that only the individuals over 70 millimeters long fed on fish eggs. Most of the individuals taken at two of the stations had apparently done some surface feeding. None of the larger specimens had fed to any extent on small crustaceans, but some of the smallest specimens had fed on aquatic insects. Table 6 summarizes the food of all channel catfish examined. Forbes (1888) found insects, especially aquatic stages of *Chironomus,* Odonata, and

TABLE 6. STOMACH CONTENTS OF SIXTY-ONE CHANNEL CATFISH (*ICTALURUS PUNCTATUS*) TAKEN AT SEVEN STATIONS, JULY 11 TO AUGUST 29, 1929 AND 1930. TOTAL LENGTH, 34 TO 101 MILLIMETERS; AVERAGE LENGTH, 57.5 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	46	75.4	53.0	9.8	123
Ephemerida, naiads (*Ephoron, Hexagenia, Caenis*)	16	26.2	6.8	0.5	5
Trichoptera, larvae	10	16.4	2.8	0.2	2
Homoptera (Cicadellidae)	8	13.1	4.3	0.3	8
Chironomidae, larvae	40	65.6	24.0	7.7	120
Chironomidae, pupae (*Chironomus, Pentaneura*)	28	45.9	11.6	0.9	9
Ceratopogonidae, larvae	3	4.9	0.4	0.1	2
Crustacea	40	65.6	33.1	17.7	264
Cladocera (*Bosmina, Daphnia, Diaphanosoma, Latona, Leptodora, Sida*)	32	52.5	27.6	16.4	264
Copepoda (*Cyclops, Diaptomus, Epischura*)	9	14.8	3.1	1.1	28
Amphipoda (*Gammarus*, etc.)	7	11.5	2.4	0.2	6
Arachnida (Hydracarina, Araneida)	2	3.3	0.2	0.1	2
Pisces, eggs	5	8.2	1.9	4.3	200
Nematoda	13	21.3	1.5	0.5	8
Debris	45	73.8	10.3	----	----

Ephemerida, to make up 44 per cent of the food; vegetable food such as algae and *Potamogeton,* 25 per cent; Mollusca, 15 per cent; and fishes, 10 per cent. In 38- to 120-millimeter specimens, Sibley (1929) found 45 per cent Chironomidae and 25 per cent *Gammarus;* miscellaneous insect larvae made up the remainder. Ewers and Boesel (1935) found chiefly midge larvae and pupae to have been eaten by Buckeye Lake specimens.

Spot-tail Minnow (*Notropis hudsonius*)

Evidently the spot-tail minnow (Table 7) feeds on different animals in different environments, and the specific type of food taken does not vary regularly with the size of the fish. The following summary of various station catches, all made in the summer of 1929, will support the preceding statement. Fifteen 19- to 33-millimeter fish contained 88 per cent Entomostraca (chiefly *Leptodora kindtii*); eleven 23- to 31-millimeter fish contained 75 per cent terrestrial insects (principally adult midges); eleven 24- to 41-millimeter fish contained 70 per cent Entomostraca; five 28- to 47-millimeter fish contained 85 per cent *Daphnia retrocurva;* five 34- to 41-millimeter fish contained 100 per cent Entomostraca (chiefly *Sida crystallina*); five 30.5- to 49-millimeter fish contained 100 per cent *Daphnia retrocurva;* twenty-one 34- to 54-millimeter fish contained 62 per cent aquatic insects (chiefly caddice-worms); ten 55- to 69-millimeter fish contained 65 per cent *Daphnia retrocurva;* eight 75.5- to 86-millimeter fish contained 69 per cent aquatic insects (chiefly elmid larvae). In the size-range studied, it was generally true that smaller

TABLE 7. STOMACH CONTENTS OF 110 SPOT-TAIL MINNOWS (*NOTROPIS HUDSONIUS*) TAKEN AT TWELVE WESTERN LAKE ERIE STATIONS, JUNE 27 TO SEPTEMBER 8, 1929. TOTAL LENGTH, 19 TO 87 MILLIMETERS; AVERAGE LENGTH, 43.0 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	62	56.4	38.6	5.1	120
Ephemerida, eggs	3	2.7	1.3	1.8	120
Ephemerida, naiads	7	6.4	2.6	0.1	1
Thysanoptera (Thripidae)	4	3.6	1.9	0.8	50
Trichoptera, larvae	15	13.6	6.8	0.2	3
Coleoptera (Elmidae), larvae	5	4.5	4.0	0.6	28
Diptera	51	46.4	17.8	1.5	12
Chironomidae, larvae	25	22.7	6.2	0.7	9
Chironomidae, pupae	26	23.6	4.4	0.4	8
Chironomidae, adults (*Oricotopus*, etc.)	14	12.7	6.5	0.3	12
Crustacea	54	49.1	41.2	9.1	130
Cladocera (*Alona, Daphnia, Leptodora, Sida*)	48	43.6	37.0	8.6	130
Copepoda (*Cyclops, Epischura*)	7	6.4	2.9	0.2	6
Ostracoda	1	0.9	0.1	0.2	20
Hydracarina (*Torrenticola*)	10	9.1	2.2	0.3	16
Debris	41	37.3	17.9	--	---

and larger individuals from the same environment were more likely to feed on the same thing than were individuals of like size from different environments. Sibley (1929) found crustaceans (mainly *Diaptomus sicilis*) in 15-millimeter specimens, whereas 35- to 100-millimeter fish had eaten 41 per cent fish eggs, 17 per cent plant material, and 10 per cent midge larvae, with some earthworms, adult midges, etc. Allin (1929) found Chlorophyceae abundant.

Mimic Shiner (*Notropis volucellus volucellus*)

Insects constituted over half of the food of the specimens studied (Table 8). Especially prominent were mayfly naiads and midge pupae and adults. Entomostraca such as *Leptodora kindtii* were also abundant. Although the smallest specimens in the series had fed entirely on Entomostraca and the largest ones largely on insects, there is no clear-cut evidence of a definite progressive change in feeding as the size of the fish increases.

TABLE 8. STOMACH CONTENTS OF SIXTY MIMIC SHINERS (*NOTROPIS VOLUCELLUS VOLUCELLUS*) TAKEN AT SIX WESTERN LAKE ERIE STATIONS, JUNE 27 TO JULY 23, 1928 AND 1929. TOTAL LENGTH, 29 TO 71 MILLIMETERS; AVERAGE LENGTH, 43.8 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	45	75.0	54.6	3.3	100
Ephemerida, naiads	9	15.0	14.1	0.2	1
Diptera	30	50.0	22.2	2.9	100
Chironomidae?, eggs	2	3.3	2.1	2.1	100
Chironomidae, larvae	9	15.0	1.5	0.2	2
Chironomidae, pupae	14	23.3	8.0	0.3	3
Chironomidae, adults (*Chironomus*, etc.)	8	13.3	7.8	0.2	4
Mycetophilidae, adults	3	5.0	1.5	0.1	2
Hymenoptera, adults (Chalcididae, etc.)	4	6.7	1.7	0.1	2
Crustacea	20	33.3	23.2	0.9	8
Cladocera (*Daphnia*, *Leptodora*)	19	31.7	22.0	0.9	8
Arachnida (Hydracarina)	5	8.3	1.3	0.1	3
Nematoda	3	5.0	0.3	0.1	2
Debris	28	46.7	19.9	----	----

Northern Sand Shiner (*Notropis deliciosus stramineus*)

In this species the stomach contents were invariably in very poor condition and consisted largely of debris (Table 9). Insects made up most of the organisms present. Among the aquatic stages, midge pupae and midge larvae were most abundant. A variety of terrestrial insects and some fish eggs were also present. Crustacea were inconspicuous. Sibley (1929) found midge larvae and plant material in 33-millimeter specimens.

TABLE 9. STOMACH CONTENTS OF THIRTY-SEVEN NORTHERN SAND SHINERS (*NOTROPIS DELICIOSUS STRAMINEUS*) TAKEN AT FIVE WESTERN LAKE ERIE STATIONS, JULY 12 TO SEPTEMBER 18, 1928 AND 1929. TOTAL LENGTH, 41 TO 70 MILLIMETERS; AVERAGE LENGTH, 57.8 MILLIMETERS.

Food organisms	Number of stomachs	Percentage of total number of stomachs	Average percentage of food by volume	Average number of animals	Greatest number of animals in any one stomach
Insecta	24	64.9	33.5	1.4	6
Ephemerida, naiads	2	5.4	1.9	0.1	1
Homoptera (Cercopidae, Cicadellidae, Aphididae)	7	18.9	4.0	0.2	2
Coleoptera, larvae (Elmidae?)	2	5.4	2.8	0.1	1
Diptera	18	48.6	16.3	0.8	5
Chironomidae, larvae	7	18.9	4.4	0.4	5
Chironomidae, pupae	8	21.6	6.9	0.2	1
Chironomidae, adults	5	13.5	4.8	0.1	1
Hymenoptera, adults (Chalcididae)	2	5.4	3.1	0.1	1
Crustacea	11	29.7	3.3	0.5	5
Cladocera (*Leptodora*, etc.)	5	13.5	2.3	0.3	5
Copepoda (*Diaptomus*, etc.)	4	10.8	0.4	0.1	1
Pisces, eggs	2	5.4	2.2	0.4	12
Algae, filamentous	2	5.4	0.2	----	----
Debris	32	86.5	60.0	----	----

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MIGRATION AND DEPLETION OF STOCKED BROOK TROUT

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INTRODUCTION

During the 1936 fishing season projects were established to ascertain the migration of stocked brook trout, recovery of stocked trout by anglers, and the depletion of the stocked fish on several New Hampshire streams. CCC enrollees were assigned to approach fishermen and question them politely. It was explained that the information was being collected to provide a basis for a more efficient stocking policy and to provide better fishing. It is estimated that over 70 per cent of the fishermen were contacted. Enough data were obtained on two streams to permit a general discussion of results.

Bear Brook in Suncook, New Hampshire, was selected as a typical heavily fished southern New Hampshire trout stream. Several ex-

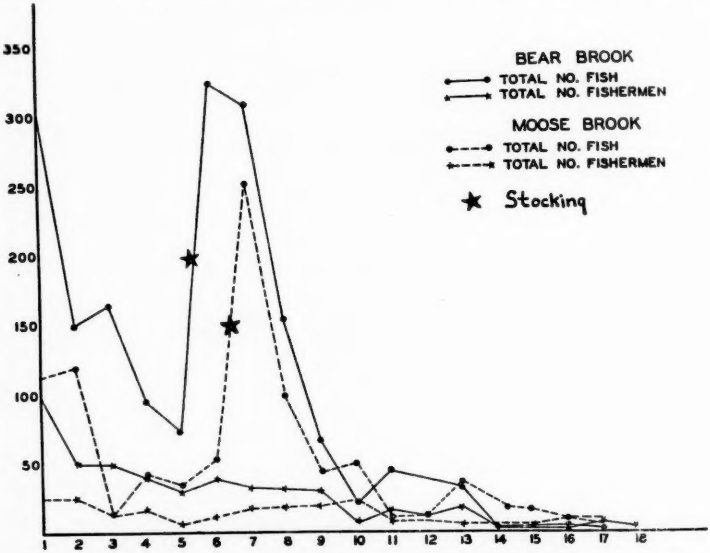

Fig. 1.—Weekly catch of trout and number of fishermen throughout the fishing season.

perimental stockings were made. In the fall of 1935 (after the fishing season) 2,000 legal brook trout were stocked, and in the spring of 1936 (prior to the opening of the fishing season) an additional 2,000 legal brook trout were planted which theoretically would establish a reserve of 4,000 legal fish for spring fishing. During the first month (May) of the open season the fishing declined rapidly and might have been described as poor fishing by the end of May, at which time only 15 per cent of the 4,000 previously stocked fish had been removed. During the first week of June the stream was again stocked with 2,000 legal fish, and the fishing immediately improved (Figure 1) with a similar obvious increase in the number of fishermen in spite of the fact that the fish were planted secretly. The 2,000 trout stocked in June during the open season produced better fishing than the 4,000 trout stocked in the fall and early spring. Five hundred of the 2,000 trout were tagged. Seventy per cent of the tagged fish stocked in June were removed by the end of three weeks as follows: end of first week, 45 per cent taken; end of second week, 60 per cent taken; and the end of the third week, 70 per cent taken. Fishing had again declined to the poor fishing level. Figure 2 portrays the depletion of stocked trout.

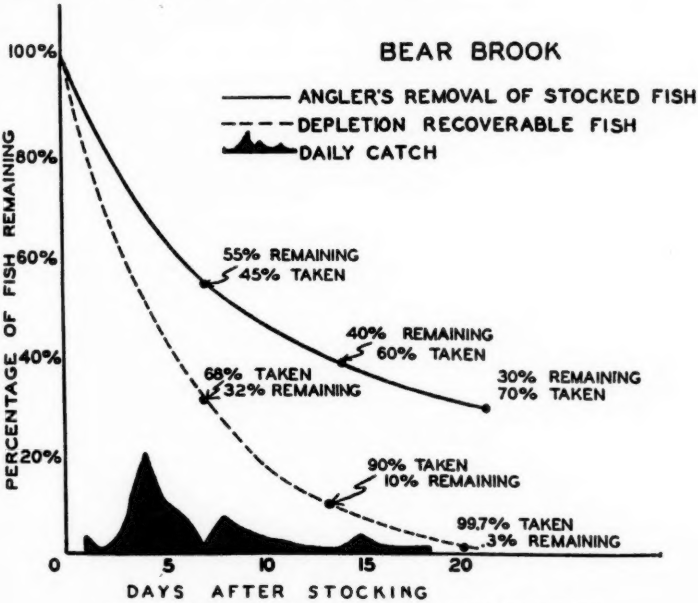

Fig. 2—Depletion of stocked brook trout by angling.

Except that there was generally better fishing when there were more fish in the brook, day to day records of catch show no definite or consistent relation to the number of fishermen, number of hours fished, or miles of stream fished. Fifty per cent of the total number of fish taken during the season were removed on Saturday (20 per cent) and Sunday (30 per cent).

Fewer fish were taken per fisherman's hour when there was a large number of anglers on the stream than when a smaller number was present. The total number of trout taken during an angling day varied rather directly with the total number of fishermen, but the number of trout taken per unit of effort varied more or less inversely with the number of fishermen present.

Movement of Stocked Trout

Data were obtained on the location where tagged fish were caught and recorded on a large scale map by CCC boys who were not aware of the original stocking place. The movements of the trout are of interest. Sixty-eight per cent of the 380 recaptured tagged trout were returned with sufficient data to be of value in this study. Eighty per cent of these had migrated downstream, while approximately 20 per cent migrated upstream during the twenty days they remained in the brook. The mean downstream migration during the twenty-day period was 1,268 feet; upstream, 1,454 feet. The greatest distance upstream that a tagged fish was taken (at end of twenty

MIGRATION OF STOCKED TROUT

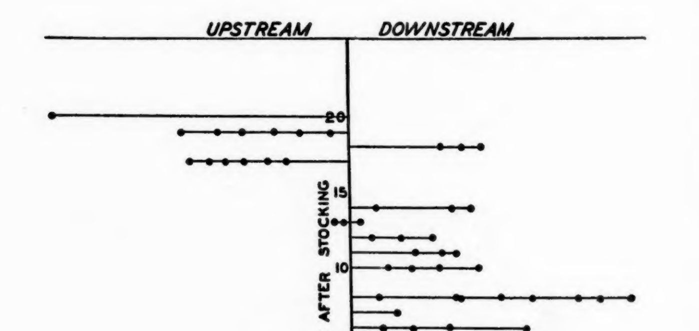

Fig. 3—Movement of stocked brook trout in Bear Brook.

days) was 3,900 feet, and downstream (end of eight days) was 3,700 feet. The mean distance of movement from the point of stocking was approximately 1,300 feet. Figure 3 illustrates the movement of the stocked trout.

The stocking of tagged fish was further utilized to ascertain the efficiency of stocking methods. Five hundred tagged fish were placed in one hole in the stream, and at the same time 1,500 untagged trout were scattered throughout the length of the stream. The stock of tagged trout was depleted in three weeks, whereas the trout scattered throughout the stream produced good fishing for approximately five weeks. Assuming that the ratio of depletion of tagged and untagged trout is representative, it is obvious that a scattered stocking of fish is superior to a concentration of fish in a small area.

Moose Brook

Moose Brook in Gorham, New Hampshire, was selected as a typical heavily fished northern New Hampshire trout stream. The results obtained on this stream generally parallel those obtained in Bear Brook except that fewer tagged fish were stocked, and because of this the movements of stocked trout could not be interpreted. Five hundred legal brook trout stocked in Moose Brook in the fall of 1935 likewise produced distinctly poorer fishing than 500 legal trout stocked during the open season of 1936. Stocking during the open season produced better fishing over a longer period of time (Figure 1).

Summary

The data seem to indicate that the best results will be obtained from brook trout plantings in heavily fished New Hampshire streams if the fish are well distributed throughout the brook and if small, repeated, open season plantings are made instead of fall and early spring plantings.

Most of the tagged trout were caught downstream from the point of stocking, but the last few were taken upstream from the place where they were planted. Trout planted at intervals along the brook were not caught out as quickly as those which were liberated in large numbers at one place. In both Bear Brook and Moose Brook, fishing grew poorer from the beginning of the season in May until it was revived by stocking in June. In both brooks, maintenance of fishing appears to depend on repeated stocking. There is nothing in the data to indicate that the catch of trout in Bear Brook in 1936 was increased by the stocking in the fall of 1935. Although stocking in these brooks is necessary to provide good fishing, "fisherman's luck" still plays a big part in determining the catch.

No attempt is made to explain the migration of the trout downstream, but it is believed that the situation may be entirely different at some other time of the year.

OBSERVATIONS ON TRICHODINID INFECTION (CYCLOCHAETOSIS) OF *SALVELINUS FONTINALIS* (MITCHILL)

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ABSTRACT

The results are given of a study of Trichodinid infection of speckled trout. In the absence of cirri the present parasite is assigned to the genus *Trichodina*. A brief description of the form is given.

Experiments were undertaken to produce a resistant stage for the transmission of this parasite, but without result. Simple transmission is shown to develop a heavy infection rapidly, and dead or dying parasitized fish are demonstrated to be a possible source of contamination for a great length of time—10 to 140 hours, depending upon the temperature. In the absence of a resistant stage, the drying of troughs and instruments is a satisfactory sterilization of equipment. As a prophylactic measure, a salt bath using a 3 per cent solution for two minutes (as commonly recommended) gives complete elimination of the parasite, but only when a volume of at least 50 cubic centimeters of solution is used for each fish of fingerling size. Salt solution becomes inactive very rapidly, an effect not to be considered as the result of dilution. Glacial acetic acid (1:1,500 for fifteen seconds) is a preferable solution on this account and is more positive in action. Proper treatment with these solutions can completely eliminate the parasite and bring about rapid healing of damaged tissues.

Trichodinid infection (Cyclochaetosis) of speckled trout and other salmonoid fishes is well-known in the hatchery rearing of such species, and has been recorded in Europe (Plehn, 1924; Doflein, 1916, and others) and on this continent (Davis, 1929) but owing to the slight mortalities associated with infection by this protozoan, it has attracted little attention. The present work was undertaken during a study of this form as it appeared in a group of about one hundred speckled trout fingerlings held under crowded conditions in a tank at the Department of Zoology, McGill University. The fish came to the department from the Province of Quebec Fish Hatchery at St. Faustin.

A month after these fingerlings had been transferred to a 40-gallon tank at the University, the infection first appeared. In less than a week, parasitism was heavy and the majority of the fish showed signs of a fraying of the dorsal and caudal fins. In many fish, this process continued to a point where these fins were frayed down to their bases. The frayed fins and a marked increase in the mucus secretion on the back and head which gave a bluish tinge to these areas were distinctive of the infection. As is often seen, the fish dived repeatedly and rubbed the sides of their bodies along the sand on the bottom of the tank. Scrapings of the mucus from the back and fins gave large numbers of parasites for a cursory examination, but for more detailed

work—staining 'in toto' or sectioning—it was found best to obtain specimens by dipping infected fish in hot Bouin's fixative.

The *Trichodina* which parasitize speckled trout are remarkably large and flattened, having a diameter of 0.132 millimeter and a height of 0.028 millimeter. This large size, the flattened form, and the presence of twenty-six to twenty-nine hooks on the chitinous ring place the present specimens in a species distinct from that described by Mueller (1932) which infected rainbow trout, from that illustrated by Davis (1929), and from that shown by Plehn (1924). The majority of the present specimens possess twenty-six hooks. The study of living, stained, and sectioned material clearly shows the adoral and posterior rings of cilia, but fails to reveal the presence of an anterior ring of cilia. These observations bear out Mueller's statement that these forms belong to the genus *Trichodina* and not to the *Cyclochaeta* to which they had previously been referred. The increase in numbers of *Trichodina* is rapid and occurs in waves. Although at some times no dividing forms may be found, at other times fully 20 per cent of the specimens taken will be undergoing binary fission. Reproduction takes place in the manner described by Diller (1928) and Mueller (1932). Binary fission takes place in the vertical plane and yields daughter forms 0.113 millimeter in diameter, with a large rod-shaped nucleus and only twelve to fourteen hooks on the chitinous ring. Such specimens were abundant on trout three or four hours following experimental infection.

Trichodina sp. occurred in greatest numbers on the back and fins, but in the weakened fish it was common to find *Trichodina* abundant on the sides of the body, on the head, and fins. In such fish some *Trichodina* were present in the mouth, on the gills, and even—although rarely—in the cloaca and rectum. Normally *Trichodina* lives only five to ten minutes when removed from the host in a sample of mucus. Disintegration sets in rapidly, but if a freshly dead or dying trout is transferred to a petrie dish containing water the *Trichodina* will escape slowly from the host and settle on the bottom of the dish. This process continues for several hours. Such specimens lived two to three hours after leaving the host and it appears that the liberation of the parasite is correlated with the sloughing of slime from the dead fish. This offers an excellent means for the continuance of infection by this parasite. It was found by repeated experiments that while at room temperatures (22.0°C. to 25.0°C.) live *Trichodina* escaped from the dead host during a period of eight to ten hours and were still capable of infecting other trout at the end of this time, at lower temperatures the process is greatly prolonged. At 11.0°C. live parasites were present on the dead host up to the end of 72 hours, whereas at 4.5°C. *Trichodina* survived for 140 hours after the death of the host.

The above experiments on survival were undertaken in an effort

to develop a resting or resistant form of this parasite. Starvation experiments and the culture of this form were equally unsuccessful. Similarly, the keeping of specimens under conditions of low oxygen content, and the slow drying of dishes containing infected fish were both without result. None of these experiments produced a resting form, and it was not found possible to carry on the infection through a period of drought, either partial or complete. Clean trout failed to develop an infection when placed in fresh water in containers which had previously held infected fish and which had been permitted to become dry before the introduction of the clean fish.

On the other hand, direct transmission is readily produced. Twelve hours after the introduction of a single infected trout into a sterile container containing two clean fish, the latter had become equally heavily infected as the former and without apparent diminution in the number of parasites on the original host. Similar and even more rapid infection followed the introduction of a dead or dying trout under the same conditions. It was found that the handling of an uninfected fish following the handling of an infected specimen without cleaning the operator's hands or instruments readily transmitted the disease, but such transmission of the parasite was completely prevented by the drying of the instruments and hands. This form of transmission is greatly facilitated by the heaviness of the mucus on seriously infected trout.

The above experiments indicated that the simple drying of troughs, other containers, and instruments is a sufficient sterilization against this parasite. However, it is necessary to subject the fish themselves to baths of disinfectant solution in order to free them from this form. The use of 3 per cent saline is commonly advocated. This solution was tried and found effective only after an immersion of at least two minutes and when relatively large volumes were used. The salt solution removes the mucus from the skin of the fish but unfortunately the solution loses its effectiveness very rapidly and becomes inactive. At least 50 cubic centimeters of solution are required for each fingerling about 3 to 4 inches long. The immersion of two fingerlings in 100 cubic centimeters of solution destroyed the action of the bath, and trout placed in the same solution were later not freed from the parasite. On the other hand, glacial acetic acid baths (1:1,500 in water and used for fifteen seconds) retain their ability to cause disintegration of the mucus and to kill the parasite much longer than does the salt solution. No particular advantage appeared to recommend the use of the more dangerous formalin, copper sulphate, or the less positive potassium permanganate baths sometimes suggested for prophylactic treatments. Following the proper use of salt or acetic baths, the damaged fins healed rapidly and the mucus coat became normal.

The above infection, without treatment, lasted for three months and during this time there was no diminution in severity. At no

time was there an excessive mortality which could be laid directly to this disease, but the fish continued throughout this period in very poor condition. Correlated with the Trichodinid infection were slight infections by forms of *Chilodon, Costia,* and *Ichthyopthirius,* but these did not become serious. On the other hand, a wave of infection by *Octomitus salmonis* Moore occurred which reached a peak in eight days and then gradually lessened until at the end of the fourth week the *Octomitus* infection had completely disappeared.

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STUDIES ON THE EFFECT OF COAL WASHINGS ON STEELHEAD AND CUTTHROAT TROUT

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INTRODUCTION

Extensive coal mining operations take place in the foothills of the Cascade Range of mountains in Washington. The coal chiefly mined is semi-bituminous in type, low in sulphur content and high in waste materials such as slate and sand particles. Segregation of slate, sand, and fine coal is carried on by means of mechanical washers. The machines not only allow the coal to be washed, but to be sorted and conveyed to proper bins. During the washing operation water is forced by considerable pressure through jets on the crushed coal as it passes on an agitation table. The agitation loosens the sand and slate particles and the water flushes and conveys the particles through the screens of the agitation platform. The openings in the screens allow pieces smaller than a BB shot to escape. This form of pollution passing out into public waters, prompted the following experiment to determine its effect on trout.

Cedar River was chosen for the experimental studies because of the number of coal mines and washing units emptying debris into its course, and because of its accessibility to the laboratory located at the School of Fisheries, University of Washington.

METHODS

Fish were held in a polluted area and in an unpolluted area by means of screened boxes which are termed fish boats. These were made of screen in the form of cylinders, 4 feet in height by 18 inches in diameter. A 12-inch section of one end of the boat was made removable to facilitate entrance and a ring was fastened to the apex of this cover for attachment purposes, which was useful for holding the boat in midstream or when lowering and raising it in lake work. The fish boat was covered with one-half inch, 20 gauge galvanized wire cloth.

OBSERVATIONS

Young steelheads (*Salmo gairdnerii*) averaging 6 inches in length were used in the first experiment. Ten fish were confined in each of two boats. No. 1 boat was placed in a polluted area and No. 2 (control) was placed above in an unpolluted area. Observations were made of each group of fish at 15-minute intervals. At the end of one hour, those confined to the polluted area commenced to show genuine distress. They exhibited a general tendency to remain at the lower end of the fish boat, and a definite increase in the pulsations of the gill openings. Within 1½ hours the first of the

fish succumbed and the entire lot of fish in boat No. 1 died within 2½ hours. The fish in boat No. 2, or the control lot, which were kept upstream in unpolluted water, were left overnight without loss of a single fish.

Examination of the dead fish disclosed heavy secretions of mucus covering the fish and the gills. Solid masses of coal dust and slate particles adhered to the mucus. The gills had faded in color. A quantity of coal dust and slate particles was found in the stomachs of the fish. The blood vessels of the liver and heart stood out prominently, giving a hæmorrhagic appearance to both organs.

A similar test was conducted with young cutthroats (*Salmo clarkii*) ranging from 1 to 2 inches in length. A screen box was constructed by wiring two egg baskets together. In this experiment coal washings had a much more toxic effect on smaller fish as the entire lot died in thirty minutes. The control lot showed no mortality. The above test was conducted in Squalicum Creek, near Bellingham, Washington. To make absolutely sure that the coal washings were causing the deleterious results, fish were kept overnight in the water pumped from the mine, but there was no mortality.

Economic Aspects

The question arose as to what disposition to make of the debris. The standard flow of water necessary to operate a one-unit washer averages about 250 gallons of water per minute. Several samples of a gallon each, taken from the washer drains, averaged 3 ounces of solids. During a twelve-hour working day, which is the schedule during the fall and winter, approximately 22½ tons of solids enter the river for each unit used. On property owned by one of the coal companies, pools were constructed of sufficient size to allow for the accumulation of the total water output during one working period of twelve hours to permit the accumulation to settle or filter before the next day's load was introduced. The coal and slag deposited at the end of the week was piled in a convenient corner of the basin. After a sufficient quantity of this material had been collected it was sold at a price of $1.25 per ton as a cheap grade of stoker coal. Its incineration value on several tests amounted to 25 to 28 per cent ash. Salvaging costs were paid for by the sale of this low grade fuel.

Experimental tests proved that wastes from coal washings are injurious to trout; that waste material could be sold at a price to cover the cost of salvaging it; and that the removal of this waste material left the streams in condition fit for trout.

GROWTH, HABITS, AND FECUNDITY OF THE CISCOES OF IRONDEQUOIT BAY, NEW YORK

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ABSTRACT

This paper presents a study of ciscoes of Irondequoit Bay, New York, and deals with their migration, age and time of spawning, associated species at the time of spawning, predators, and conservation. This study is based on the age determinations of 505 specimens, on the calculations of the length at the end of various years of life of 500 of these ciscoes, and on the examination of the ovaries of 104 fish.

The ciscoes of Irondequoit Bay belong to two related forms, but further study will be needed before their taxonomic status may be established satisfactorily.

Calculated lengths were usually lower than actual lengths at capture of fish of the same age. The curve of growth in length is typical for the species and is the same for both males and females. However, the females generally run heavier than the males at corresponding lengths.

Fecundity was estimated by the volumetric method. It was determined by actual counts that this method involved an error of 5.1 per cent. Fecundity increased with age, fish in age group VIII producing three to four times as many eggs as the group II individuals. Although there appears to be a great deal of variation in the fecundity at a particular age, the tendency is toward an increase with an increase in length and weight.

INTRODUCTION

It is apparent from the studies of a number of investigators that the ciscoes or lake herring belong to a very plastic and variable group of fishes. A great deal of study and experimentation on the various forms will be necessary before a true picture of their relationships may be obtained. It is not the purpose of this paper to discuss the taxonomy of ciscoes but rather to present a study of the ciscoes of Irondequoit Bay from the point of view of life history, habits, and conservation.

Irondequoit Bay, a remnant of the old preglacial Genesee River, lies about 3 miles northeast of Rochester, New York. The bay is about 4 miles long, three-fourths of a mile wide, and has a maximum depth of about 84 feet. The outlet of the bay into Lake Ontario allows fish to migrate back and forth between the two bodies of water. Although some of the more slender *Leucichthys artedi artedi* type of cisco are present in the bay, entering no doubt from Lake Ontario, the majority are a deep bodied type close to the form Koelz (1929) describes as *L. artedi albus*. It is with this deep bodied form of Irondequoit Bay that this paper is mainly concerned. A striking characteristic of this type is the great variation in the form of the caudal fin. There are specimens with extremely asymmetrical tails as well as those in which the tails are symmetrical and intermediate in shape.

Materials and Methods

A collection of 526 specimens was made during the fall and early winter of 1935 and 1936. Most of the fish were taken during or immediately preceding the spawning period in the latter part of November and the first week in December and therefore were presumably at the end of a growth year. The majority of specimens was selected at random from pound-net catches of the New York State Conservation Department.

Scale samples were placed in small envelopes on which the following data were recorded for each specimen: total and standard length in millimeters, weight in grams, sex, maturity, date of collection, method of collection, and locality. All lengths and weights were taken while the fish were still fresh. The standard length was measured from the tip of the snout to the last vertebra, whereas the total length was measured from the tip of the snout to the end of the lower lobe of the tail. Weights were recorded to the nearest tenth of a gram by use of an Ohaus trip balance. The stage of maturity was easily recognized as the fish were near the spawning period. The scale samples were taken from the left side of the body below the dorsal fin and above the lateral line. Scales from this area were found by Van Oosten (1929) to vary the least in size and shape and to be best suited for measurements.

In preparing the scales for study they were soaked in water and the epidermis removed. With the aid of a binocular microscope scales were selected for mounting according to their distinctness and symmetry. Three scales were mounted on glass slides employing a glycerine-waterglass medium as used by Creaser (1926). For the examination, determination of age, and measurement of the scales a photomicrographic apparatus similar to that described by Van Oosten (1923) was used. It was found helpful for comparison and study of the scales to make photographs of each by means of the apparatus mentioned above.

Ages were determined by counting the number of annuli or winter rings between the summer growth areas. Accessory annuli or summer checks were encountered in some scales but their position with respect to the true annulus, the presence of less "cutting over" in the posterior lateral field, and the fact that they do not destroy the continuity of the growth field as does the annulus made them quite easily recognizable. It is customary to record age from the time of hatching in the spring. The young of the year are considered members of age-group O, and during their second summer are members of age-group I. A fish in its sixth year having five fully formed annuli is placed in age-group V.

The theoretical length of a fish at the end of each year of life and its rate of growth may be calculated from scale measurements. The scales were measured by placing a millimeter ruler on the projected image or photograph of the scale so that it bisected the pos-

terior area. Van Oosten (1929) found that for the lake herring measurements based on scale diameters gave the best results. The scales measured in 1935 were projected at a magnification of 21.5 diameters whereas a magnification of 16.5 was used in 1936. By the application of the following well known formula the length of the fish at each annulus was calculated:

$$\frac{\text{Length of fish at n annulus}}{\text{Standard length at capture}} = \frac{\text{Diameter of scale within n annulus}}{\text{Total diameter of scale}}$$

This formula is based on the assumption that the scales grow in pro-

TABLE 1. AGE, AVERAGE LENGTH IN MILLIMETERS AND WEIGHT IN GRAMS OF MALES AND FEMALES COMBINED, AVERAGE LENGTH AND WEIGHT OF MALES, AND AVERAGE LENGTH AND WEIGHT OF FEMALES FOR 505 IRONDEQUOIT BAY CISCOES.[1]

Age group	Year of collection	Total length, males and females	Standard length, males and females	Weight, males and females	Standard length, males[2]	Standard length, females[2]	Weight, males	Weight, females
0	1936	168 (8)	138	39.4	-----	-----	-----	-----
I	1935	262 (1)	225	149.8	-----	-----	-----	-----
I	1936	270 (2)	221	178.0	-----	-----	-----	-----
II	1935	293 (49)	248	286.0	249 (35)	258 (14)	279.5	349.9
II	1936	312 (15)	258	327.5 (14)	259 (4)	258 (11)	318.1	338.6 (10)
III	1935	339 (8)	282	405.5 (5)	277 (4)	286 (4)	375.8	528.8 (1)
III	1936	337 (211)	281	428.8 (204)	281 (69)	281 (139)	425.4	437.4 (130)
IV	1935	353 (10)	297	348.6 (7)	299 (7)	292 (3)	498.1	-----
IV	1936	373 (3)	309	559.5	313 (1)	307 (2)	611.5	533.0
V	1935	370 (21)	312	547.6 (15)	311 (14)	314 (7)	545.6	576.8 (1)
V	1936	377 (22)	314	595.8	313 (13)	314 (9)	585.0	615.8 (7)
VI	1935	387 (14)	329	686.5 (11)	327 (7)	331 (7)	641.3	765.6 (4)
VI	1936	394 (54)	328	702.1 (47)	326 (22)	329 (32)	704.3	818.4 (26)
VII	1935	397 (5)	337	814.0	337 (5)	-----	814.0	-----
VII	1936	406 (71)	339	794.8 (59)	339 (26)	338 (45)	796.7	790.3 (33)
VIII	1936	426 (11)	361	916.8 (10)	366 (4)	358 (7)	975.7	883.9
IX	1936	442 (1)	365	1,047.0	-----	365 (1)	-----	1,047.0
X	1936	469 (2)	394	1,256.0	390 (1)	398 (1)	1,233.0	1,280.0

[1]Numbers of individuals used for averages are indicated in parentheses. Unless indicated otherwise the same number of fish was used for comparable lengths and weights.

[2]All fish were sexually mature except the 0 group for which sex was not determined, the I group which were all immature, and nine out of a total of twenty males and twenty-six out of a total of twenty-nine females of age-group II which were immature.

portion to the body length and was shown to be applicable to the scales of the lake herring by Van Oosten (1929).

Acknowledgments

The writer wishes to acknowledge his obligation to Dr. Ralph Hile, Associate Aquatic Biologist, U. S. Bureau of Fisheries, for advice concerning scale reading; to Dr. Emmeline Moore, Chief Aquatic Biologist, New York State Conservation Department for authorization to obtain 100 female ciscoes with eggs from the pound-net catches of the State; to Mr. Peter Miller, of the Conservation Department, for specimens of the Irondequoit Bay cisco and for data regarding stripping operations; to Dr. J. D. Hood and Dr. Robert Ramsey, of the University of Rochester, for helpful suggestions, and to Mr. William Duden for assistance in scale reading.

Especial appreciation is felt for the interest and cooperation of Dr. Sherman C. Bishop, of the University of Rochester, under whose careful supervision this study was made.

Growth Rate Studies

Data concerning age, maturity, average length and weight of males and females combined, average length and weight of males, and average length and weight of females of the Irondequoit Bay cisco are shown in Table 1 for 505 specimens.

The results of age determination and measurement of scales from 500 ciscoes are presented in Table 2.

TABLE 2. AVERAGE ACTUAL STANDARD LENGTHS AT THE TIME OF CAPTURE, CALCULATED LENGTHS AT THE END OF EACH YEAR OF LIFE, AND INCREMENT OF GROWTH, FOR AGE-GROUPS I TO X OF 500 IRONDEQUOIT BAY CISCOES.

Number of specimens	Year class	Year of capture	Age group	Standard length at time of capture	Calculated length at end of year of life: 1	2	3	4	5	6	7	8	9	10
2	1926	1936	X	394	143	203	228	254	280	305	326	344	355	373
1	1927	1936	IX	365	130	206	247	268	298	313	327	337	363	——
11	1928	1936	VIII	361	133	204	234	256	282	302	327	342	——	——
5	1928	1935	VII	337	128	191	224	265	290	294	315	——	——	——
71	1929	1936	VII	339	131	200	229	251	280	301	320	——	——	——
14	1929	1935	VI	329	138	201	230	255	285	303	——	——	——	——
54	1930	1936	VI	328	131	196	233	262	291	328	——	——	——	——
21	1930	1935	V	312	130	207	232	280	290	——	——	——	——	——
22	1931	1936	V	314	129	195	236	265	288	——	——	——	——	——
10	1931	1935	IV	297	130	199	239	271	——	——	——	——	——	——
3	1932	1936	IV	309	122	208	256	286	——	——	——	——	——	——
8	1932	1935	III	282	120	190	245	——	——	——	——	——	——	——
211	1933	1936	III	281	136	198	241	——	——	——	——	——	——	——
49	1933	1935	II	248	140	203	——	——	——	——	——	——	——	——
15	1934	1936	II	258	138	210	——	——	——	——	——	——	——	——
1	1934	1935	I	225	132	——	——	——	——	——	——	——	——	——
2	1935	1936	I	221	116	——	——	——	——	——	——	——	——	——
Grand average—calculated length					131	200	236	264	287	306	323	340	359	373
Grand average—annual increment					131	69	36	28	23	19	17	17	19	14

The average standard length at the time of capture as well as the average calculated length at the end of each year of life are shown. Since the standard lengths at the time of capture were taken at the end of the growing season, one may compare these lengths of age-group I with calculated lengths at the end of the second year of life, and the standard length at capture of age-group II with calculated lengths at the end of the third year, etc. If this comparison is made it will be found that there is no large discrepancy present especially in old age groups. In general the calculated lengths are lower than the corresponding actual lengths at the time of capture, which is in accord with the findings of other investigators including Van Oosten (1929) and Hile (1936). The average differences between actual lengths of fish of age-groups I to IX and calculated lengths of individuals in age-groups II to X are as follows: 23, 17, 17, 16, 7, 5, 2, 2, 8 millimeters. In every instance except the comparisons of the calculated length of age-group X fish with the actual length of age-group IX, and of the calculated length of age-group VIII with the actual lengths of age-group VII, the calculated lengths are lower than the actual.

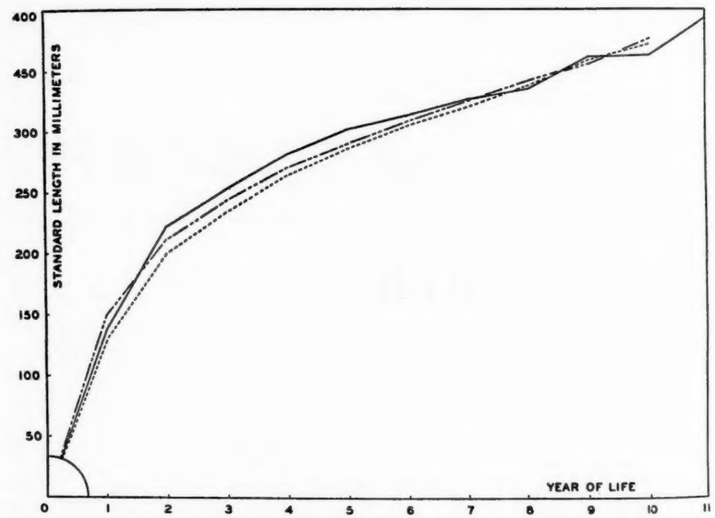

Figure 1.—Comparison of growth in length at the end of each year of life of the Irondequoit Bay cisco as determined from actual, calculated, and corrected calculated lengths.

Actual length at capture
Corrected calculated lengths
Calculated lengths

It was suggested by Fraser (1916) that discrepancies in the calculated growths of fishes were due to the fact that the fish grew to a certain length before scale formation began. Thus this preliminary growth is not recorded on the scale. Van Oosten (1929, p. 306) writes concerning late scale formation, "Lee expresses Fraser's (1916) correction for the former factor in the form of a formula, $L_1 = C + \frac{V_1}{V}(L-C)$, in which C is the length of the fish when the scales first appear, L the length of the fish at death, V the scale dimension, L_1 the computed length at the end of the first year, and V_1 the scale dimension to the first annulus."

According to Van Oosten (1929) the lake herring attains a length of 35 to 40 millimeters before scale formation begins. Assuming the length to be 35 millimeters, corrected calculated lengths using Lee's formula were computed. A comparison of actual, calculated, and corrected calculated lengths is shown in Figure 1.

The curve for growth in length (Figure 2) is typical for the species. It is shown by this curve, and has been found by other investigators, that growth is greatest during the first three years of life, the growth rate decreasing progressively during these years from 131 to 36 millimeters. The growth of the later years is fairly constant but shows

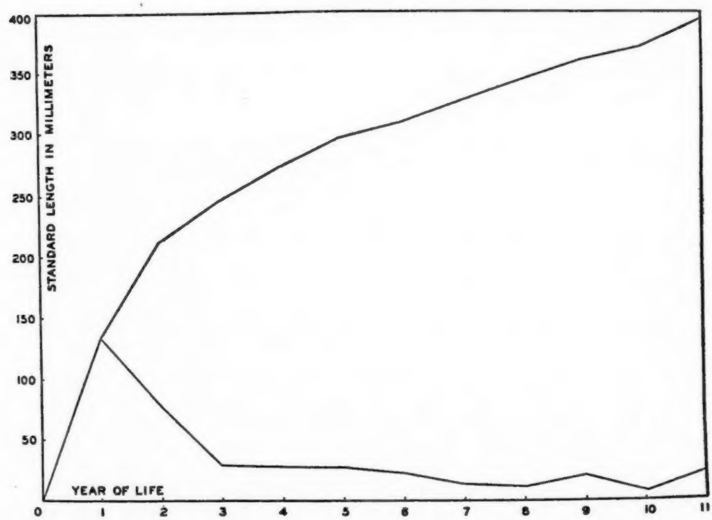

Figure 2.—Average growth in length at the end of each year of life for the Irondequoit Bay cisco based on actual and calculated measurements combined of 500 specimens taken in 1935 and 1936. Also increment of growth.

a tendency to decrease gradually as the fish become older. The growth in length of males and females is practically the same (Table 1). Differences which appear are no doubt partly due to insufficient numbers of specimens to provide representative averages.

The average growth in weight is shown in Figure 3. In contrast to the growth in length, the growth in weight increases with age. The comparison of growth in weight for males and females is shown in Table 1. When sufficient numbers of specimens are present for comparison, the females in general average heavier than the males at corresponding lengths.

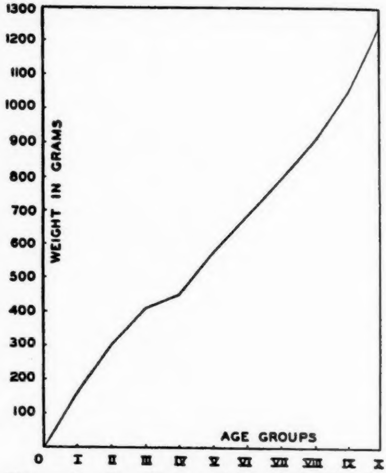

Figure 3.—Growth in weight of the Irondequoit Bay cisco.

Migration

Migration Between Lake and Bay. The migration of ciscoes from Lake Ontario into Irondequoit Bay was demonstrated by a number of ciscoes caught in trap nets set in the outlet of the bay where it enters the lake. The trap nets were placed with the entrance of the tunnel directed toward the lake in about 2 or 2½ feet of water, where the current was fairly swift. On November 13, 1936 ten ciscoes (six males, three females, and one immature specimen) were taken during migration from the lake into the bay. The water temperature was 3.8° C.

Migration in Bay. During the fall of 1936 ciscoes were first observed near the surface and toward the shore about the second week in September, when specimens were taken during carp seining operations with a 524-foot bag seine. On September 17, 1936 twenty-seven specimens (seventeen females and ten males) were taken in a seine haul on the east shore of the bay opposite Point Pleasant, where the water temperature was 59.4° C. The following day a haul of sixty-one specimens (twenty-nine males and thirty-two females) was taken at the same locality. The apparent absence of ciscoes in this area before the second week in September can perhaps be explained by thermal conditions. Cahn (1927) states concerning *L. artedi,* "The species has a seasonal migratory rhythm in a vertical plane, correlated with and determined by the shifting of the thermocline."

Ciscoes became more and more numerous in the shallower areas throughout the month of October as the spawning season approached. The fairly common opinion that the males precede the females to the spawning grounds, which has been proven by some investigators including Cahn (1927), does not seem to hold true in Irondequoit Bay. Early pound-net catches showed males and females to be of approximately equal abundance. However, during the latter part of the spawning period the males seemed to be fewer than the females.

Spawning Notes

The youngest mature males and females in the collection belonged to age-group II and had completed their third summer's growth. Among the sixty-four age-group II fish forty-four were mature and twenty were immature. The mature fish of age-group II consisted of thirty males and fourteen females and the immature individuals numbered nine males and eleven females. All fish in age-group III and older were mature and all individuals in age-groups I and O were immature. Therefore, it may be assumed that the ciscoes of Irondequoit Bay mature at the end of their third or fourth summer.

In Irondequoit Bay spawning extends over a period of about two to two and one-half weeks during the latter part of November and the first part of December, depending on temperature conditions. It has been noted by employees of the New York Conservation Department, when obtaining ciscoes for stripping, that fish in the south end of the bay appear to ripen a few days in advance of those at the north end nearer the lake. This would seem to indicate a difference in temperature between the north and south end of the bay. Mr. Raymond Norton, of the New York State Conservation Department, informed me that temperatures at the south end of the bay run a few degrees lower than those at the north end, probably because of the inflow of colder water from Irondequoit Creek. During 1935 the spawning period began about November 27 and ended about December 12, while in 1936 it extended approximately from November 24 to December 5. The above dates were based on the number of ripe fish taken in the pound nets by the Conservation Department. Spawning areas were located by taking bottom samples with an Ekman dredge. Eggs were taken on a mud bottom at depths ranging from 4 to 7 feet.

Associated Species at the Time of Spawning. The most abundant species associated with the cisco during the spawning season in Irondequoit Bay, as shown by pound-net catches of the Conservation Department, were ***Ameiurus nebulosus*** and ***Cyprinus carpio.*** Other less numerous species were: ***Perca flavescens, Stizostedion vitreum, Pomoxis sparoides, Pomolobus pseudoharengus, Esox lucius, Aplites salmoides, Helioperca macrochira, Petromyzon marinus,*** and ***Dorosoma cepedianum.***

Food of the Cisco. Examination of thirty-four stomachs from Irondequoit Bay ciscoes taken in November during the spawning period showed that the fish had been feeding principally on Cladocera, Copepoda, and cisco eggs. Twenty-four of a total of thirty-four stomachs contained cladocerans, fifteen contained copepod remains, twenty-three contained cisco eggs, and three contained fish remains. Four stomachs from fish taken September 17, 1936, held large numbers of cladocerans and copepods, one stomach contained a Diptera larva, and another fish remains.

Predators of Cisco Eggs

The examination of stomach contents from thirty-six specimens of the common bullhead, *Ameiurus nebulosus,* taken in Irondequoit Bay near the spawning grounds on December 9 and 11, 1935 showed that twenty stomachs contained cisco eggs and sixteen had none. The number of eggs taken by individual bullheads varied from a few to two hundred. The abundance of *Ameiurus nebulosus,* as evidenced by its presence in pound-net catches of the Conservation Department, is such that it may be a menace to the cisco.

That the ciscoes eat their own eggs is shown by an examination of stomach contents of fish taken during the spawning period. Among the thirty-four stomachs opened twenty-three contained remains of cisco eggs.

It has been shown by other investigators that the perch, *Perca flavescens,* and the mud puppy, *Necturus maculosus,* both of which are present in Irondequoit Bay, destroy cisco eggs. Pritchard (1931) writes concerning the perch, "This species is by far the worst destroyer of eggs among the fish that live over the cisco spawning grounds." In regard to the mud puppy, Jordan and Evermann (1902) state, "The mud puppy, commonly known as 'lizard' or 'water-dog' by the people along the lakes, is especially destructive. During the month of January, 1897, many of these animals were pumped up with the water supply of the Put-in-Bay (Ohio) station. The stomachs of a considerable number of them contained whitefish and cisco eggs, the contents of one stomach being 288 whitefish eggs and four cisco eggs."

Conservation of the Cisco

Among the factors to be considered in formulating measures for the conservation of the cisco are relative abundance of various year classes, age at maturity, longevity, fecundity, stripping, and predators. The stripping of the Irondequoit Bay cisco by the New York State Conservation Department has been undertaken each year since the fall of 1928. The question arises whether or not the stripping of these fish helps to conserve the species. For the following reasons I doubt whether the practice is helpful:

1. No selection is made in regard to age of fish to be stripped.

Since stripping kills the fish the younger specimens spawn only once or twice whereas if they were allowed to spawn naturally in the bay they would no doubt spawn five or six times. Therefore, a great number of potential eggs are destroyed when the younger fish are killed. It is apparent from the data of Table 1 that the younger fish spawning for the first or second time (age-group III) are the most numerous of the specimens represented in the samples. Age-group VII ranks second in abundance. Since the fecundity of age-group VII fish was found to be two or three times greater than the productivity of fish spawning for the first time or second time (Table 4) it would, I believe, be better to strip only these older fish, if any.

2. The fish hatched from the stripped eggs are planted in Lake Ontario and Lake Erie when very young (eyed eggs or fry), and I believe are as greatly exposed to predators as are the eggs which are deposited naturally on the bottom of the bay.

Fecundity of the Cisco

Few studies concerning the correlation of fecundity—the number of eggs produced by a single female per year—with age, length, and weight have been made. No such study has been made of the cisco. A series of 104 mature but "hard" females just previous to spawning was obtained for this study. It is necessary to obtain fish near the spawning period as at this time only are the eggs nearly uniform in size. The egg complements were removed from the fish and placed in individual jars containing 5 per cent formalin. The standard length in millimeters and the weight, including eggs, were recorded for each specimen. Fecundity was determined by means of the volumetric method, based on the assumption that the total number of eggs present, if uniform in size, is proportional to the volume of the egg mass. The following procedure was used:

1. The egg mass was placed in a sieve and the excess formalin allowed to drain off.
2. The egg mass was then transferred to a graduated cylinder and the total volume determined.
3. One cubic centimeter of eggs plus some connective tissue was measured and the number of eggs counted.
4. The number of eggs in one cubic centimeter multiplied by the total volume gives the fecundity.

In Table 3 the fecundity as estimated by the volumetric method and the fecundity as determined by actual egg counts are compared. The average error for nine ovaries was 5.1 per cent. An error of 14 per cent in one specimen (not included in the average) was no doubt due to the immaturity of the eggs and proportionately greater amount of connective tissue as compared with the other complements. Mark Hall (MS.) found that in using the method on the cisco an error of only 3 per cent was present.

The difference between estimated fecundity and actual counts is due principally to the presence of ovarian connective tissue. Water

or preservative which adheres to the eggs may be considered to be negligible.

TABLE 3. COMPARISON OF ACTUAL AND ESTIMATED FECUNDITIES.

No. of sample	Number of eggs per cubic centimeter	Total estimated volume in cubic centimeters	Number of eggs, estimated	Number of eggs, actual count	Per cent error	Age group
119	253	34	8,602	8,146	—6	II
214	180	57	10,260	8,864	—14	II
348	235	62	14,570	13,560	—7	III
318	220	75	16,500	15,695	—5	III
358	229	64	14,656	14,005	—5	III
204	241	92	22,172	20,496	—8	III
314	207	69	14,283	13,640	—5	III
311	241	50	12,050	11,813	—2	III
211	215	143	30,745	30,060	—3	VI
207	194	199	38,606	36,851	—5	VIII

The average fecundity, length, and weight of the various age groups among the 104 fish examined are shown in Table 4. The data show that fecundity increases with age. The age-group VIII females produced three to four times as many eggs as the age-group II females. This increase in fecundity may also be correlated with an increase in the length and weight of the fish (Table 5).

TABLE 4. AVERAGE FECUNDITY, LENGTH, AND WEIGHT OF 104 IRONDEQUOIT BAY CISCOES.

Age group	Number of specimens	Standard length in millimeters	Weight in grams	Average number of eggs per female
II	8	255	338.3	13,723
III	78	282	456.4	21,824
V	2	317	580.8	27,846
VI	9	324	733.6	38,606
VII	4	329	781.7	35,928
VIII	3	356	938.8	48,999

The data of this table indicate that the heavier and longer fish of an age group tend to be the most productive although considerable variation occurs.

TABLE 5. RELATION OF FECUNDITY TO LENGTH AND WEIGHT OF CISCOES OF AGE GROUP III.

Standard length in millimeters	Average number of eggs per female	Weight in grams	Average number of eggs per female
260-265	16,126	351-375	15,927
266-270	20,468	376-400	17,697
271-275	18,580	401-425	19,593
276-280	22,985	426-450	23,214
281-285	24,043	451-475	24,152
286-290	22,479	476-500	22,747
291-295	23,029	501-525	25,025
296-300	25,780	526-550	23,533
301-305	26,880	551-575	29,915

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FACTORS INFLUENCING FISH FOOD AND FISH PRODUCTION IN SOUTHWESTERN STREAMS

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ABSTRACT

For the past two years surveys have been in progress on the mountain streams of the Southwest. These investigations included chemical analyses, quantitative counts of bottom food organisms, a study of the physical character of the streams, and studies of the fish such as species present, relative abundance, age, and growth rate. An intensive creel census has been undertaken in several streams. An intensive study is being made on two experimental streams, one of which has been improved to the practical limit and the other left in its original condition.

The surveys have shown that vegetative cover on the watershed and especially in the canyon bottoms is of great importance in maintaining productivity. Vegetative cover is essential for retaining moisture and preventing severe floods which have been found to be the outstanding limiting factor in southwestern streams. Floods not only roll and grind the bottom materials and widen the stream bed, destroying pools and cover, but they also sweep away rich organic materials essential for an abundant bottom fauna and deposit light-colored inorganic silt which is almost barren of life. It has been found that streams not subject to severe floods for some years are much richer than those streams having frequent floods.

Studies made on the experimental streams clearly demonstrated this fact. These two streams—Upper Tonto Creek and Horton Creek—are similar in character and water supply. The unimproved stream, Tonto Creek, is, however, 0.2 mile longer and has a larger flow. Formerly it was considered the better fishing stream. Since improvement, however, an intensive creel census and food studies have shown that the improved stream, Horton Creek, is now the better stream. Last year it was found from food studies made at different times throughout the year that Horton Creek had an estimated yield of over 300 pounds more food than Tonto Creek. Also, the creel census revealed that Horton Creek yielded a greater number of fish. In addition, the catch per hour was greater on Horton Creek and the average total number of fish for each fisherman was greater. Scale studies reveal that prior to improvement the growth rate of the fish was more rapid in Tonto Creek, but since improvement it is more rapid in Horton Creek.

On the average these two streams yielded about 50 pounds of trout to the acre of stream. At the market price for trout this is a return of $30.00 an acre for meat alone, not taking into consideration the recreational value. This return is very good as compared to any southwestern land and gives a more definite idea of the real value of the fish resources of the Southwest.

Region 3 of the U. S. Forest Service undertook an extensive stream improvement program when federal emergency funds were made available for conservation work in 1933. Due to the emergency character of the work, structures were placed in many streams without a preliminary study of the environmental conditions. The need of surveys made previous to the environmental improvements was recognized, however, and in 1934 stream and lake surveys were made in several forests by the U. S. Bureau of Fisheries in co-operation with

the Forest Service. Due to the lack of funds, this work was not carried on by the Bureau of Fisheries in 1935.

Late in 1935, Region 3 of the Forest Service made a special arrangement with the Bureau of Fisheries whereby the staff of that region was allowed to carry on lake and stream surveys in the forests of New Mexico and Arizona.

The general purpose of these surveys was to learn more about the mountain trout streams and lakes of the Southwestern Region so that an intelligent system of environmental improvement and fish management could be outlined. Since little was known about the fish of New Mexico and Arizona, it was believed advisable to discover the species present and the species best adapted to local conditions. It was also desired to determine the productivity of the various waters and to form a stocking budget for them which would indicate where to stock, the species to plant, the number and size to release, and the most suitable time to liberate them. Of equal importance was the recognition of the factors that influence fish food and fish production, a knowledge of which is basic to any improvement of environmental conditions. It was also thought advisable to carry on studies to determine the effect of stream improvement and to evaluate its results.

Actual survey work began early in 1936. The survey methods and the means of evaluating the environmental improvements were similar to those used by the writer in his Michigan work. Physical, chemical, and biological studies were made. The condition of the watershed and the canyon bottoms, erosion, use by live stock, cover, fall, and altitude were noted. Quality of pools and riffles, the current velocity, and temperatures of the water were recorded. Length of pools and riffles, average depths and widths, and the areas of different bottom types were tabulated. Chemical studies consisted of the determination of dissolved oxygen and carbon dioxide, alkalinity, and hydrogen-ion concentration.

Fish collections were made for the purpose of determining species present and to secure scale samples for the determination of age and growth rate. Quantitative and qualitative studies of the bottom food organisms were made on the various bottom types, such as rubble-gravel, silt, and bed rock, so that the productivity and the dominant forms on each bottom type might be known. Stomach analyses were made in conjunction with these food studies in order to discover the forms most preferred by the trout. Age, growth rate, and creel census studies were used in the determination of productivity and the species most suited to a particular water. Scale readings in combination with food studies are considered of great importance in the formation of a stocking budget.

Floods and accompanying or resulting erosion are considered the most important limiting factors in the productivity of Southwestern streams. When surface cover is severely damaged or destroyed, sur-

face runoff is increased, resulting usually in floods. These flood waters and the eroded materials which they carry lessen the productive capacity of the streams in many ways. By rolling and grinding the bottom materials floods destroy many of the aquatic organisms which serve as food for trout. They also sweep the rocks clean of food organisms, depositing them in streamside pools, out on flats, or in piles of debris along the banks where they are destroyed.

Quantitative counts made in streams of the Tonto Forest in Arizona, before and after the severe spring flood of 1937, revealed that the amount of bottom food had been reduced almost half by the floods. Many instances were noted where aquatic insects had been deposited on the flats where they died. Four large tipulid larvae were found dead in a shallow depression less than 25 square feet in area. It was impossible, of course, to find the small forms such as the midge larvae, mayflies, and stoneflies but they were undoubtedly killed in great numbers. Examination of the drift piles along the banks revealed large numbers of organisms which had been swept to destruction. An even more destructive action of the floods is the reduction of the productive capacity of the streams by the sweeping away of the mucky organic materials and debris, such as leaves, twigs, bits of bark, and the deposition of mineral silt. The reduction in the yield of food organisms through the scouring of mucky areas by floods and the deposition of mineral silt is clearly demonstrated by samples taken from one square foot of typical bottom areas at periodic intervals throughout a year. These samples revealed that on the average the mucky bottom pools in a stream not subject to severe flood yielded 179 pounds of food to the acre, whereas in anther stream, areas covered with mineral silt yielded only 43 pounds of aquatic organisms to the acre or less than one-fourth as much.

The reduction in the amount of bottom food, due largely to floods, is also shown by measurements made in four streams in the Tonto Forest. These four streams, Ellison Creek, upper Christopher Creek, Dry Dude Creek, and East Verde River, are all similar in that they are formed by springs which emerge just below the Tonto Rim and flow through a limestone-sandstone country. They differ, however, in that the watersheds of East Verde River and Dry Dude Creek do not have such a dense vegetative cover as those of Ellison and upper Christopher Creeks. The former streams are therefore subjected to floods while the latter have not had severe floods for a number of years. Samples one square foot in area were taken from typical bottom types of these streams and the amount of food per area was calculated from the averages. It was found that in Ellison and Christopher Creeks the riffles had an average of 364 pounds of food per acre, and the pools 187 pounds per acre, but in Dry Dude and East Verde the riffles yielded an average of only 81 pounds of food per acre and the pools 22 pounds per acre.

It has been found that floods and erosion limit production in other

ways than by reducing the food supply. They destroy pools and cover and choke the streams with silt. They also erode the banks and widen the streams, making them shallow, open and otherwise unfavorable for trout. The streams are sometimes converted into open boulder-gravel washes which are not suited for any form of fish life or they may become muddy and so warmed due to exposure that they are not favorable for trout. Findings to date indicate that muddy sections of streams produce less trout food and fewer trout than the clearer sections.

The character and condition of the cover on the watershed and in the canyon bottoms are determining elements in the productivity of a stream. When the cover is adequate, floods are not severe and soil erosion does not proceed so rapidly. Trees and shrubs along the streams are beneficial because they protect the banks against the erosive action of floods, thereby keeping the streams narrow, which condition is conducive to the formation of pools and undercut banks. A forest cover is also of benefit to a stream since it fertilizes the stream by providing materials such as duff, humus, twigs, leaves, and bits of bark which collect in quiet areas to form the mucky flats so rich in food organisms.

Studies of food production in various streams have made it clear that temperature is important to productivity. The warmer streams generally produce more food. When other conditions are similar, the lower, warmer portion of a stream yields more pounds of food per acre than the upper, colder portion of the same stream. In lower Horton Creek, which is about 10 degrees warmer in summer than upper Horton Creek, the rubble-gravel riffles contained on the average throughout a period of a year 268 pounds of food organisms per acre; the same type of riffle in the upper reaches of the stream yielded only 207 pounds per acre, or a difference of 61 pounds per acre in favor of the lower riffles. The same situation was observed in the Mora River, where the lower riffles yielded 144 pounds of aquatic organisms per acre, while the riffles in the upper portion of the stream yielded only 94 pounds to the acre. On a stream in which erosion is active in the lower sections, however, this condition is often reversed. Thus, the detrimental effects of erosion and floods overcome the beneficial influences of the higher temperatures and decrease the food yield.

Scale studies show that the trout grow faster in the lower reaches of Horton and Tonto Creeks than they do in the upper, colder portions of the same streams. Table 1 gives the calculated length as determined from the scale readings of trout from both the upper and lower portions of Tonto and Horton Creeks. According to these samples, the average growth in the lower portions of these streams exceeded that in the upper portions by 1.2 and 1.9 inches respectively in three growing seasons.

TABLE 1. AVERAGE LENGTH IN INCHES OF TROUT FROM UPPER AND LOWER HORTON AND TONTO CREEKS AT THE END OF EACH GROWING SEASON.

Stream section	First season	Second season	Third season	Number of fish
Lower Horton	3.43	6.56	9.17	20
Upper Horton	2.79	5.35	7.26	24
Lower Tonto	4.45	7.25	8.55	9
Upper Tonto	3.61	5.76	7.34	12

When the stream surveys were extended to different forests it was observed that the streams in some areas were more productive and had a greater population of aquatic organisms. It appeared that the streams flowing through limestone formations or formations containing limestone were richer than those flowing over volcanic or granite and other acid rock formations. When food production per acre was compared with the alkalinity of the water, that is, the content of carbonates, bicarbonate, and hydroxides, it was found that those streams having a high methyl orange alkalinity invariably had a high food production, if floods were not severe. Streams in the Tonto Forest in Arizona, such as Horton, Tonto, Ellison, and upper Christopher Creek, which flow through basic rock formation below the Tonto Rim and have a relatively high methyl orange alkalinity, are, as indicated by quantitative studies of bottom food organisms, much more productive than streams in the Santa Fe Forest, such as Holy Ghost, Mora, Winsor, Cave, and Panchuela Creek, which largely flow over acid rock formations and have a relatively low methyl orange alkalinity. All these streams are similar in temperature range and they are all largely free from severe floods, especially those in the Santa Fe Forest. A comparison of the methyl orange alkalinity, temperatures, and the yield of food per acre from the riffles, pools, and bed rock of these streams is made in Table 2. It will be noted

TABLE 2. COMPARISON OF METHYL ORANGE ALKALINITY WITH FOOD PRODUCTION.

Name of stream	Temperatures ° F.		Methyl orange alkalinity	Average food yield in pounds per acre		
	Air	Water		Riffles	Pools	Bed rock
Horton	74	57	116	229.0	179.2	23.9
Tonto	78	58	111	175.3	167.7	5.8
Ellison	84	65	101	306.7	277.9	----
Christopher	74	60	129	421.7	95.8	----
Holy Ghost	69	59	59	71.8	9.5	----
Mora	67	60	49	94.3	----	----
Winsor	64	50	60	81.4	55.5	----
Cave	71	51	44	99.0	----	----
Panchuela	76	56	70	81.0	56.0	2.8

that food yield varies greatly on the different bottom types but that it is always greater in the streams flowing over the basic rocks and having the greater methyl orange alkalinity. In the mountain trout streams of the Southwest, bed rock and mineral silt bottoms have

been found to be the poorest in food yield while boulder-rubble riffles, plant beds, and pools having boulder bottoms with debris have been found to be the richest. This relationship is, in general, in accordance with findings in Michigan as reported by the writer at the preceding meeting of the Society.

Studies made to date by the Forest Service in the forests of New Mexico and Arizona indicate that a favorable environment is of prime importance and is the principal factor that influences trout production. In view of this fact, numerous attempts have been made and several methods used to improve the habitat for trout. It has been realized that trout stream improvement must begin, not in the stream itself, but on the watershed and in the canyon bottoms. If the stream habitat has become less favorable for trout, it is usually due to some change in the watershed which has produced the unsatisfactory conditions. If this situation is to be remedied and lasting improvements made, it cannot be done by treating the unfavorable effects of the changes on the watershed which are manifested in the stream but it must be done by first restoring favorable watershed conditions.

This reclamation has been accomplished quite successfully by the Forest Service through the prevention of forest fires and control of grazing. The restoration of natural conditions in this way has greatly benefited streams through the reduction of soil erosion and the prevention of floods. Another successful method of stream improvement carried out by the Forest Service is stream bottom fencing to protect the stream banks and stream-side trees and shrubs. Forest officers report great benefits from this practice during the last few years. Streams so managed have formed definite, narrow channels abounding in pools, riffles, and cover; food has increased; temperatures have become more favorable; and fishing has improved.

As previously pointed out, improvement of the aquatic habitat by introduction of devices into the streams has been undertaken during the past few years. Since this method is relatively new, the results of such improvements and their value are not generally known. There has been some question concerning the practicability of such so-called environmental improvements for increasing the productivity of mountain streams. It seemed advisable, therefore, to conduct experimental work on this problem in conjunction with the routine stream studies in order to check the effects of the introduction of such structures into the streams and to evaluate the final results of changes produced. Two Arizona streams, Horton and upper Tonto Creeks, were selected for these experimental studies. Horton Creek had been improved almost to the practicable limit, while upper Tonto Creek had been left in its original condition. Improvement work was begun in Horton Creek in 1933 and was continued during the summers of 1934 and 1935. Most of the improvements were installed in 1934.

These two streams are much alike and therefore are well suited for testing the results of stream improvement. Both receive their permanent water supply from large springs which emerge just below the Tonto Rim. Chemical analysis of the springs indicates that the water supply of the two streams is similar. The streams flow over the same formation and are close together, being separated by a narrow projection extending out from the Tonto Rim. These streams differ mainly in that Horton Creek has improvement structures in it, while Tonto Creek is in its natural condition, is somewhat longer and has a greater flow. A detailed physical survey was made of these two streams to determine the extent of these differences. The results of this survey are summarized in Table 3. It will be noted that Tonto Creek is 0.24 of a mile longer than Horton Creek and exceeds it in water surface area by 0.77 of an acre. The total area of the pools in Horton Creek is greater than the pool area of Tonto Creek due to the improvement devices which have created large pools. Tonto Creek was formerly considered the better trout stream; and during the past five years has been stocked with over twice as many trout as Horton Creek.

TABLE 3. SUMMARY OF MEASUREMENTS ON TONTO AND HORTON CREEKS.

	Average depth in inches		Average width in feet		Length in miles		Area in acres	
	Horton	Tonto	Horton	Tonto	Horton	Tonto	Horton	Tonto
Riffles	7	10	12	13	2.40	2.86	3.65	4.85
Pools	17	19	15	13	1.14	0.92	2.11	1.58
Totals					3.54	3.78	5.76	6.43

The differences in the productivity of the improved stream, Horton Creek, and the unimproved stream, Tonto Creek, are being tested in three ways: by quantitative studies of the bottom food organisms; by the determination of the growth rate of the trout in the two streams from scale studies; and by a creel census. Quantitative bottom samples have been taken periodically for more than a year from typical portions of all bottom types. These samples were weighed and measured and the average yield per acre for each classification calculated. All bottom types in Horton Creek have been found to be richer in food than the corresponding ones in Tonto Creek. In Horton Creek the riffles yielded an average of 229 pounds of food per acre, while those in Tonto Creek yielded an average of 175 pounds per acre; the Horton Creek pools yielded an average of 179.2 pounds per acre, while the Tonto Creek pools yielded an average of 167.7 pounds per acre; the bed rock in Horton Creek yielded an average of 24 pounds per acre, while that in Tonto Creek yielded an average of 5.7 pounds per acre. Thus production per acre in Horton Creek exceeded that in Tonto Creek as follows: riffles 53.7 pounds;

pools 11.5 pounds; and bed rock 18.2 pounds. The total yield of food from Horton Creek as calculated from the samples taken exceeded the total yield of Tonto Creek by 40 pounds, even though the area of Tonto Creek exceeds that of Horton Creek by almost an acre and the flow of Tonto is greater.

Studies of the growth rate of the trout from Horton and Tonto Creeks show that the stream improvements have increased the growth rate in Horton Creek. In September of 1936 scale samples were taken from fish collected from both the upper and lower sections of these streams. The scales were studied and the lengths of fish at the end of each growing season were calculated. The scales from 3-year-old trout furnished data on the growth rate in Horton Creek before and after improvement and the growth rate in Tonto Creek during the same period of time. The average growth rates of trout from both streams for each year are tabulated in Table 4. This table

TABLE 4. AVERAGE RATE OF GROWTH OF RAINBOW TROUT IN HORTON AND TONTO CREEKS BEFORE AND AFTER THE STREAM IMPROVEMENTS IN HORTON CREEK BECAME EFFECTIVE IN 1935.

Stream	Average growth in inches during 1934	Average growth in inches during 1935	Average growth in inches during 1936	Number of fish
Upper Tonto Creek	3.61	2.15	1.58	12
Upper Horton Creek	2.79	2.56	1.91	24
Lower Tonto Creek	4.45	2.83	1.27 (4 fish)	9
Lower Horton Creek	3.43	3.13	2.61	20

shows that in 1934, before the stream improvement devices had become effective, the average annual growth in upper Tonto Creek exceeded that in upper Horton Creek by 0.82 inch; and the annual growth in lower Tonto Creek exceeded that in lower Horton Creek by 1.02 inches. In 1935 and 1936, however, after conditions in Horton Creek had become stabilized, the average annual growth of rainbow trout in upper Horton Creek exceeded the average of the rainbow trout in upper Tonto Creek by 0.41 inch in 1935 and 0.33 in 1936. Similarly, the average annual growth of the rainbow trout from lower Horton Creek exceeded the average growth of the rainbow trout from lower Tonto Creek by 0.30 inch in 1935 and by 1.34 inches in 1936. It is concluded that the stream improvements are responsible for the improved growth rate of the Horton Creek trout, since no changes were noted other than those induced by stream improvement.

Creel census studies for the purpose of determining the fish yield from the improved and unimproved stream were initiated on Horton and upper Tonto Creeks at the beginning of the 1936 fishing season and are being continued during the 1937 season. These streams are ideal for the taking of such a census, since there is only one road leading to them and a man stationed at their junction can contact all fishermen when they are going to and returning from the two

streams. The results of the creel census on these two streams are summarized in Table 5. The returns for the season of 1936 and for the season of 1937 up to August 1 are given. These results clearly show that Horton Creek has provided the better fishing. In 1936 more fish were removed from Horton Creek than were removed from Tonto Creek; the average catch per hour was also greater on Horton Creek; and the average production per acre of water area was 8.64 pounds greater in Horton Creek.

TABLE 5. SUMMARY OF THE CREEL CENSUS RETURNS FROM HORTON AND TONTO CREEKS FOR THE SEASON OF 1936 AND FOR THE 1937 SEASON UNTIL AUGUST 1.

Year	Stream	Number of fishermen	Total catch of legal trout	Average size in inches	Undersized trout returned	Total hours fished	Average number of fish per hour	Pounds of trout removed	Yield of trout in pounds per acre	Meat value per acre
1936	Tonto	267	1,422	8.2	721	1,023	1.39	293	45.60	$27.36
	Horton	260	1,491	8.2	631	926	1.61	307	54.24	32.54
1937	Tonto	263	1,152	7.6	907	801	1.43	190	29.50	17.70
	Horton	435	1,822	7.4	2,190	1,388	1.31	233	41.20	24.72

Tabulations for the 1937 season up to August 1 indicate even greater differences in the number of fish taken from the two streams. Although the trout season was only a little more than half spent, Horton Creek had yielded 670 more trout than Tonto Creek and had produced an average of 11.7 pounds more trout per acre of water area.

Since no figures are available on the recreational value of trout fishing, the actual economic returns from these two streams have been expressed simply as the meat value of the trout. In figuring these values, a market value of 60 cents per pound was used. As indicated in Table 5, the meat values per acre of water surface in Horton Creek exceeded those of Tonto Creek by $5.18 in 1936, and so far this season have exceeded them by $7.02. These figures represent a concrete measure of the value of stream improvement. When the recreational values, which are many times the meat values, are considered, it is apparent that the improvements on Horton Creek are practical and beneficial. It appears, therefore, that the value of mountain streams can be increased by means of stream improvement.

Aside from the value of these figures in determining the differences in productivity of an improved and unimproved stream, they are also of interest in that they denote the trout production in mountain streams of the Southwest. The value of the trout from these two streams for meat alone exceeds the generally estimated value placed on all phases of fishing. The average return of nearly $30.00 an acre for meat from these two streams would be considered a good return from any type of agricultural land. As the recreational values may

be conservatively estimated as many times the meat values, it seems obvious that the real value of the game fisheries of the country have been greatly underestimated.

When the results of the stream surveys and the studies made on improved and unimproved streams during the past year and a half are tabulated and correlated, certain conclusions are reached in regard to the mountain streams of the southwestern portion of the country. Studies of the productivity of fish and fish food clearly indicate that floods and soil erosion are the significant factors limiting production. It is also apparent that an adequate ground cover is essential if the streams are to approach their potential productive capacity. The value of stream-side trees and shrubs in the prevention of bank erosion, in the maintenance of favorable environmental conditions and in the fertilization of streams by the addition of organic materials has been demonstrated many times. Water temperatures and alkalinity have been found to be an influence in the production of trout food and of trout. In addition, the experimental studies made on Horton and Tonto Creeks have demonstrated that the use of stream improvement devices increases food production, increases the growth rate of the trout, and increases the trout yield.

THE SITUATION OF THE FISHING INDUSTRY IN MEXICO

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I am firmly convinced that we have immense natural resources within our territorial waters and in the extraterritorial waters off our shores. Much has been written by naturalists well known the world over, about the different species that live in our waters—the local, the pelagic, as well as the migratory species. In the portions of our country washed by the Pacific and Atlantic Oceans, there have long existed important fisheries—important both because of their situation and of the products exploited.

In the history of our Mexican shore fisheries, those located off the Lower California Peninsula and in the Gulf of California or Sea of Cortez have been the pioneers. Our experience in these fisheries has, however, been bitter because our Government did not obtain any economic advantage from them, but these fisheries were exploited chiefly to satisfy the industrial needs of companies located in foreign countries.

I shall now proceed to touch upon the complex nature of this problem, beginning with a brief exposition of the present state of our marine fauna. Twenty-five years ago the fishing of pearls constituted a productive industry, so intensely pursued that it almost exhausted the richer pearl deposits. The exploiters never took the trouble to conserve these pearls, for their only aim was to obtain as much profit as possible out of them. Notwithstanding this exploitation, valuable beds of pearls may still be found along the Mexican coasts, in the Pacific Ocean. The pearl-fishing zones in Lower California cover an area of approximately one thousand square kilometers, including both coasts and adjacent islands. Other pearl-fishing zones, some of them of some importance, can be found off the coasts of Nayarit (Islas Marías), Jalisco, Colima, Michoacán, Guerrero, and Oaxaca States.

What shall we say about our marine mammals, fish, crustaceans, and molluscs? Simply that they have been exploited on such an intensive scale that some of them are almost extinct, while others have totally disappeared.

The larger mammals of scientific and commercial value have been exploited also by pirates who have enriched themselves at the cost of the extinction of those valuable species. The predominant species are:

The black whale, *Megaptera nodosa*, occurs in the south from September to March. Few are to be found in April, and it is exceptional to see one in May. Many of this species appear off both coasts of

Lower California and other places along the Mexican shores, in the Pacific Ocean from 18° to 28° North latitude.

The blue whale, *Balaenoptera sibbaldii,* is regularly found off the coast of Lower California from March to May, migrating toward the north.

The gray whale, *Rachionectes glaucus,* seems to have a small area for its habitat as it is only found in the waters of the western coast of California, United States and Lower California, Mexico. It is found off the Mexican coast from January to April. This species is very abundant in the inner waters of the Gulf of California, as well as in the adjacent waters of the Revillagigedo archipelago.

The hunchback whale, *Balaenoptera musculus,* is found off both littorals of Lower California, as well as along the whole Western Mexican coast. I have not been able to obtain any information about the migration of this species.

The spermaceti whale, *Physeter catodon,* according to information obtained, comes up from the Antarctic. Approximately 1,000 whales were captured during the year 1868 in the Ojo de Liebre Lagoon, located close to Sebastian Vizcayno bay (western coast of Lower California), which produced nearly 30,000 barrels of oil with a weight of approximately 5,100,000 kilograms. These figures clearly show the great quantities of these cetaceans that existed off the western coast of Lower California where they are now practically extinct, owing to careless whaling. Statistics gathered during the period from 1913 to 1935 show that only five specimens were captured during the fiscal year 1926-1927, and one specimen during the fiscal year 1927-1928.

A total of 3,290 whales of all kinds was captured from 1913 to 1935, which was constituted as follows: Black, *Megaptera nodosa,* 45.6 per cent; Blue, *Balaenoptera sibbaldii,* 34.3 per cent; California Whale, *Rachionectes glaucus,* 7.3 per cent; Hunchback, *Balaenoptera musculus* or *Megaptera versabilis,* and other species, 12.8 per cent.

According to observations made during the above period, it can be affirmed that whales coming to our coasts travel southward as far as Cape Corrientes, Jalisco, and northward not farther than Cape San Lázaro, Lower California. The black whale, *Megaptera nodosa,* travels near the coast. The blue whale, *Balaenoptera sibbaldii,* travels a little farther away from the coast.

There are migratory species of fishes that come to dwell temporarily off our shores because of the favorable temperature conditions, and the abundance of aquatic vegetation at different depths. The minor species that contribute to their food requirements are subjected to over-fishing.

The albacore, *Germo alalunga* (Gmelin), is disappearing probably due to over-fishing. Other species are the tuna, "atun," *Neothunnus macropterus,* the yellow fin of most commercial impor-

tance, living in the Pacific in a habitat no farther north than 28° north latitude; the blue fin, *Thunnus thynnus,* that comes to the western part of Lower California; the bonito, *Sarda chiliensis;* the "jurel," white meat or "Castilla," *Seriola dorsalis* (Gilbert); the "curbina" or "corbina," *Eriscion reticulatus;* the barracuda, *Sphyraena argentea* (Girard); the barrilete (skipjack), *Katsuwonus pelamis;* and the oil sardine, *Sardinella stolifera* (Jordan and Evermann). The last species lives in Lower California waters and is very abundant in the waters of the Mazatlán dockyard and some other places. The meat is rich in quality and the species has been little exploited. The filiform bone sardine, *Sardinella thusina* (Jordan and Gilbert), is abundant off the eastern coast of Lower California. The "sardina machete," *Opisthonema libertate* (Günther), is abundant in the Gulf of California, and is commonly found in shallow waters near the breakers. The yellow fin sardine, *Opisthopterus lutipines* (Jordan and Gilbert), is very abundant on the Pacific coast, especially in the breakers outside Mazatlán Bay and has many advantages as a food fish. The blue or California sardine, *Clupanodon caeruleus* (Girard), is abundant along the western coast of Lower California, reaches a length of 30 centimeters (12 inches), is very similar to the European sardine, has no teeth, and is said to spawn in the open sea. "Lenguados" (soles) with fine meat, "cabrillas" of several kinds, "pargos" of different species and splendid for food occur in our waters as do the mackerels (horse, Pacific, and Spanish), the "garropa," *Mycteroperca venadorum,* and the "totoaba," *Cynoscion macdonaldi.* The last species is confined to the Gulf of California. The swordfish, *Xiphias gladius,* and last but not least, the eel family are also represented. Among the crustaceans the lobsters and shrimps must be mentioned, but more important are the rock lobster, *Palinurus interruptus* (Randall), *Palinurus ornatus* (Fabricius), and the crabs.

Among the molluscs the members of the family Haliotidae may be mentioned. The "abulon" or "abalones," of great economic value, are as follows: red, *Haliotis rufescens* (Swains); green, *Haliotis fulgens* (Phil); black, *Haliotis cracherodil* (Leach); rugose, *Haliotis corrugata* (Gray); and yellow, *Haliotis assimilis* (Dall). The following, according to statistics, began to be exploited in 1870, without scientific control: mussels, oysters, "hachas," and barnacles.

Among the reptiles are to be found the turtles: "Cahuamo" and "Carey."

By way of addition to the above statements on the subject of our fishing zones located towards the North and their scientific and economic conditions, I wish to lay before you the results of the studies I made on my last trip to the Gulf of Tehuantepec and Gulf of Mexico (year 1935). I observed a variety of species that largely contributed to fill the necessities of the life of the region. Their common names are as follows.

Gulf of Tehuantepec

Fishes: "Ojotón Español," or "Uyaga" in the Zapotec language; "Alaguate," or "Gísu" in the Zapotec language; "Popoyote," or "Dúnu" in the Zapotec language; "Sabalote"; "Lisa"; "Cocinero"; "Berrugata"; "Picuda"; "Sierra-Boca dulce"; "Rayáshi" in the Zapotec language; "Chivo"; "Salmonete"; "Bagre" or "Cabezón" (bighead); "Huachinango"; "Curbina"; "Chapeta" (whitefish but without scales); "Jorobado"; whitefish; "Bacoco"; "Chato"; "Panchito"; "Alacrán"; "Mero Pinto"; "Cabrilla pinta"; "Cabrilla rayada"; "Pámpano"; "Gallo"; "Puerquito," or "Cuchi," in the Zapotec language; big sardine (10 inches long); middling sardine (5 inches long); small sardine (from 2 to 3 inches long); "Jurel" (black meat); "Jurel de Castilla"; "Palmera"; "Robalo"; "Barrilete" (black meat); "Loro" or "Papagayo"; "Cazón"; "Mero negro Cherna"; "Medregal"; "Sardo"; "Senteste" (medium size and white meat); "Moteta" or "botete"; "Mojarra blanca"; "Mojarra negra" and "rayada"; "Soleme" (yellow and green striped fish); "Banderilla"; "Paloma verde"; "Sol de China" (yellow and black striped, medium size fish); "Flamenco" (with a color lighter than the "huachinango"); "Javita"; sharks; devilfish; hammerhead sharks; and rays.

Crustaceans, Molluscs, and Reptiles: Lobster; prawn; shrimp "Chacal"; clams (small and black); clams (purple, large and small); clams (small and white); oysters; "Hachas"; barnacles or pig's feet; eels; sea turtle; and tortoise-shell turtle.

Gulf of Mexico

The predominant species are the following:

Fishes: "Huachinango" or red snapper; "Robalo"; "Mojarras"; mackerel; rays; sea trout; "Negrillo"; "Cabrillas"; "Jureles"; "Gallinera"; "Meros"; "Chernas"; "Cazón" or young shark; "Boquerón" or whitebait; "Maroma"; "Sábalo" or tarpon; "Ojotón"; "Pámpano"; and "Lenguados" or flat fish.

Crustaceans, Molluscs, and Reptiles: Lobster; prawn and shrimp; "Chacal"; clams; crabs; squids and cuttlefish; oysters; eels; turtles.

The species listed in the first sections are some of the most important, industrially speaking, in the northern zone of the Mexican coasts on the Pacific. These, as well as a great variety of other fishes, crustaceans, and molluscs, like those mentioned in the later sections (many of them possibly identical or similar, but with different common designations in each region) form the reserve of the natural wealth of Mexico. These have for many years, demanded careful study, classification, collection of statistics, and a conservation system based on an agreement covering both economic and scientific aspects, for the purpose of avoiding illegitimate exploitation by certain interests. A broad vision is necessary to solve the

problems brought about by the international character of our fisheries. The right to tax within territorial limits is necessary as well as modern legislation to govern waters within the jurisdictions of different States. The commercial production of fisheries resources plays a prominent part in supplying the necessities of human existence. Therefore, because this natural wealth is seriously threatened by over-fishing to meet the market demand, it is desirable to conserve and exploit this wealth in a reasonable way.

With reference to the scientific and economic aspect of this branch of industry and its value to the United States, the biggest market for our products, I wish to remind my readers that the eminent biologist, Will F. Thompson, in the relevant part of the Program of Activities for the International Fishery Agreement between Mexico and the United States, promulgated in March, 1926 and in force until 1927, stated the following: "The demand for fish has increased to such a degree, that it is quite possible that overfishing may take place, and therefore, the supplies may decrease to a noticeable extent or become extinct. This problem has warranted close attention from European countries, especially those whose coasts are washed by the North Sea. The fisheries along the shores of Canada and the United States present the same risks to the inhabitants of said countries. In fact, the demand has been continuously increasing in the last three decades and there is no doubt that it will be even greater in coming years. Whether the resources of sea life can endure this exploitation, is one of the most serious problems of the present day. This can be noticed in the fisheries along the coasts of California and if history repeats itself, the number of boats devoted to fishing in American and Mexican waters will become greater every day, and these boats will be compelled to go farther and farther South to get a cargo. Such increase in the demand may provoke a noticeable drop in production. Besides, it is logical and inevitable that Mexico will wish to protect and perpetuate its sea life resources, as well as the taxes derived from the industry. It is equally important for the inhabitants of the United States, that that food supply is not extinguished. Therefore, it is possible that it may be necessary to resort to restrictions on immoderate fishing."

The prediction contained in these expressions made eleven years ago has, as we have seen, become partially true. We observe that other countries are searching for new supplies, such as Japan whose boats now cruise off the Mexican and South American coasts to obtain the fishery products it needs. Similarly United States boats now range as far as the coasts of Central America for the same purpose.

When I say that the statements made by Thompson have partly become true, I mean that the fishing grounds located in territorial and extraterritorial waters off the Mexican coasts, have continuously increased in importance. From statistics published by the Division

of Fish and Game of California, we may learn the origin and classification of the fishery products, and it may be asserted that as regards the products landed at San Diego and San Pedro, California (especially albacore, blue-fin tunny, bonito, barrilete, and yellow-fin tunny) from 65 to 70 per cent of the production comes from the territorial and extraterritorial waters of Mexico. If we analyze the production of yellow-fin tuna exclusively, we find that it represents, out of the totals landed at those same ports, between 75 and 80 per cent; so also, other species of local range make up a considerable percentage of the fish that originated in Mexico's territorial waters.

These statements do not mean that the big demand for fish has not compelled and is not compelling fishermen to go to other sources of supply also, like Central America and Japan.

Thompson, in the fourth section of his paper, declares, with reference to the value of our fisheries, that: "Both countries, Mexico and the United States, have a common interest in most of the sea life species, as enumerated in statistics being prepared by Mr. W. L. Scofield, of the Game and Fish Commission Laboratory of the State of California . . . . Of course there is some doubt as to the truth and accuracy of said statistics, if we take into consideration the fact that fish from Mexican waters is taxed with a heavy duty.

"For example, albacore have been frequently caught in Mexican waters, perhaps not within the three mile limit, but classified as originating from extraterritorial Mexican waters. The percentage of products coming from Mexican waters, is possibly, in many species, really higher than the figures given by the statistics. This circumstance, will not, in itself, noticeably influence the problem in general, though it will directly affect statistics obtained."

Statements written and read before the International Commission definitely recognize the fishing potentialities of Mexico and her right to conserve this form of natural wealth, and to enact laws and levy taxes; therefore, considering that both countries have a common interest, I think that efforts should be made to conclude a perfect agreement that will cover the two problems now existing, economic and conservation. I believe that the other countries represented at this convention and the American powers not so represented will find it desirable to subscribe to a treaty of this kind, due to the world interest in sea products.

Therefore, I submit this study to the consideration of the delegates represented at this convention, so that they may, after discussion of the subjects presented, announce their opinions. I beg to insist that if it is desired to obtain a satisfactory treaty, it must include both fundamental aspects of the question: *the scientific and the economic.*

A SUMMARY TABLE OF SOME EXPERIMENTAL TESTS IN FEEDING YOUNG SALMON AND TROUT

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In an effort to find better foods and food combinations to feed young salmon and trout a large number of experimental feeding tests are being conducted in the Northwest. A few of the more usable of these experiments which have been completed are included in this paper. The products used as food, and reported on here, are available in quantity sufficient for commercial use in the hatcheries of this region.

The experiments were carried on under a great variety of conditions as to duration, water, temperature, species and size of fish, etc. The only uniformity was that of procedure in securing and handling the data.

The work was conducted in the hatcheries of the Bureau of Fisheries in the States of Oregon, Utah, and Washington, and at the Experimental Hatchery of the University of Washington. In all experiments the regular hatchery equipment of troughs, tanks, and ponds was used so that the results obtained should be applicable to conditions in producing hatcheries.

In using the summary table it should be borne in mind that the diets are not necessarily 100 per cent comparable. They are merely indicative of results obtained during the time the tests progressed and under the conditions as given.

The experiments were conducted in groups or series at various times and places. In the table the heavy double cross lines separate the various groups of data. A control lot fed upon a straight liver, spleen, or meat diet was included in most of the groups to act as a means of comparison. Individual lots within a group may be compared with one another, but lots of different groups may be compared in a general way only since the time of the various series of experiments and the conditions under which they were conducted were not identical.

In compiling the data the daily record sheets were worked up into a final summary sheet. The temperatures of the water were taken twice daily and averaged for the daily temperatures, which were in turn averaged for the entire period of the experiment. The lengths of the fish, initial and final, were taken from the tip of the snout to the end of the body (tail excluded) unless designated with

an asterisk in which case the total length from the tip of the snout to the shortest rays of the caudal fin was used. The weights of the fish were determined on the wet basis from the weighed samples. In weighing the fish a container with some water was balanced upon scales. The fish were counted, and all excess moisture removed by allowing them to drain in a net for 20 seconds before their transfer to the container for weighing. The weights of food as given were computed on the "as purchased" basis with the actual weights used without correction for the various water percentages contained. The efficiency factor was determined by dividing the total weight of fish produced by the total weight of food consumed or, in other words, it represents the pounds or portion of a pound of fish produced by one pound of food. The figures in the final column that show the pounds of food to produce a pound of fish are the reciprocals of the values found in the preceding column, or they may be determined by dividing the total food consumed by the total increase in fish weight.

The cost of producing a pound of fish under the condition and with the diet of each experiment was not included in the table but it may be determined readily by multiplying the prevailing price per pound of foodstuff used by the pounds required to produce a pound of fish. The costs under the price conditions prevailing at the place and time of the experiments ranged from $0.032 to $0.57 per pound of fish.

TABLE 1. A SUMMARY TABLE OF SOME EXPERIMENTAL TESTS IN FEEDING YOUNG SALMON AND TROUT

Kind of fish used	Diet	Average water temperature degrees F.	Length of experiment in weeks	Initial average length of fish in centimeters	Final average length of fish in centimeters	Percent gain in length	Initial average weight of fish in grams	Final average weight of fish in grams	Percent gain in weight	Initial number of fish in each lot	Percent mortality	Total food fed in grams	Efficiency factor	Pounds of food per pound of fish
Chinook salmon	100% beef liver	45	7	4.14*	4.58*	11	0.51	0.86	69	3,200	1.5	3,666	0.30	3.33
Chinook salmon	100% dried carp meal	45	7	4.14*	4.59*	11	0.51	1.00	96	3,200	0.4	1,302	1.20	0.83
Chinook salmon	100% dried carp meal (cooked before drying)	45	7	4.14*	4.67*	13	0.51	1.14	124	3,200	0.4	1,336	1.50	0.67
Chum salmon	100% dried carp meal	45	6	3.19*	3.56*	12	0.23	0.40	74	5,000	0.2	719	1.18	0.85
Chum salmon	100% dried carp meal (cooked before drying)	45	6	3.19*	3.55*	11	0.23	0.44	91	5,000	0.3	698	1.49	0.67
Chinook salmon	30% beef liver 70% air dried salmon meal	45	12	3.49	5.68	63	0.54	2.40	344	3,000	2.0	4,181	1.31	0.76
Chinook salmon	30% beef liver 70% commercial dried salmon meal	45	12	3.49	4.29	23	0.54	1.07	98	3,000	3.7	3,582	0.43	2.33
Chinook salmon	50% beef liver 50% air dried salmon meal	45	12	3.49	5.65	62	0.54	2.32	330	3,000	2.4	5,495	0.95	1.05
Chinook salmon	50% beef liver 50% commercial dried salmon meal	45	12	3.49	4.53	30	0.54	1.37	154	3,000	3.2	5,190	0.46	2.17
Chinook salmon	100% canned spawned out salmon	45	12	3.49	4.41	26	0.54	1.13	109	3,000	4.1	11,997	0.14	7.14
Chinook salmon	100% canned spawned out salmon and flour	45	12	3.49	4.81	38	0.54	1.38	156	3,000	3.6	13,197	0.18	5.56
Chinook salmon	30% beef liver 70% canned spawned out salmon and flour	45	12	3.49	5.49	57	0.54	2.17	302	3,000	3.4	15,666	0.30	3.33
Chinook salmon	100% beef spleen	52	8	3.34	4.05	21	0.46	1.08	135	2,000	4.0	8,345	0.15	6.67
Chinook salmon	100% beef spleen (3 days) 100% granulated dried milk (4 days)	52	8	3.34	3.91	17	0.46	0.79	72	2,000	19.2	5,245	0.10	10.00

*Total length from tip of snout to shortest rays of the caudal fin.

*Total length from tip of snout to shortest rays of the caudal fin.

TABLE 1—CONTINUED

Kind of fish used	Diet	Average water temperature degrees F.	Length of experiment in weeks	Initial average length of fish in centimeters	Final average length of fish in centimeters	Percent gain in length	Initial average weight of fish in grams	Final average weight of fish in grams	Percent gain in weight	Initial number of fish in each lot	Percent mortality	Total food fed in grams	Efficiency factor	Pounds of food per pound of fish
Chinook salmon	50% beef spleen 50% granulated dried milk	52	8	3.34	4.41	32	0.46	1.19	159	2,000	16.9	5,120	0.24	4.17
Chinook salmon	50% beef spleen 30% granulated dried milk 20% water	52	8	3.34	4.34	30	0.46	1.23	167	2,000	14.5	6,840	0.19	5.26
Chinook salmon	100% beef spleen	52	12	3.34	6.20	86	0.46	2.30	400	2,000	5.4	16,245	0.21	4.76
Chinook salmon	30% beef spleen 40% oat mush 20% Quilcene salmon meal 10% water cress	52	12	3.34	6.20	86	0.46	2.50	443	2,000	10.6	14,525	0.25	4.00
Chinook salmon	30% beef spleen 40% oat mush 20% Quilcene salmon meal 2% kelp meal and 8% water	52	12	3.34	6.43	93	0.46	2.80	509	2,000	4.4	15,200	0.29	3.45
Chinook salmon	100% beef spleen	45	12	3.33	4.58	38	0.51	1.35	165	2,000	3.8	14,810	0.11	9.09
Chinook salmon	100% frozen spawned out salmon	45	12	3.33	3.99	20	0.51	0.86	69	2,000	22.3	5,005	0.11	9.09
Chinook salmon	30% beef spleen 70% frozen spawned out salmon	45	12	3.33	4.48	35	0.51	1.20	135	2,000	15.0	10,620	0.11	9.09
Chinook salmon	30% Quilcene salmon meal 70% frozen spawned out salmon	45	12	3.33	4.71	41	0.51	1.27	149	2,000	30.3	4,510	0.23	4.35
Chinook salmon	30% salmon liver 70% frozen spawned out salmon	45	12	3.33	3.73	12	0.51	0.66	29	2,000	1.0	6,300	0.05	20.00
Chinook salmon	100% beef spleen	45	16	3.37	4.85	44	0.48	1.51	215	2,000	3.7	9,400	0.21	4.76
Chinook salmon	70% beef spleen 30% seal meal	45	16	3.37	4.71	40	0.48	1.43	198	2,000	2.3	4,700	0.39	2.56
Chinook salmon	60% beef spleen 40% seal meal	45	16	3.37	4.61	37	0.48	1.26	163	2,000	3.1	4,230	0.36	2.78
Chinook salmon	50% beef spleen 50% seal meal	45	16	3.37	4.61	37	0.48	1.32	175	2,000	3.8	3,760	0.43	2.33

TABLE 1—CONTINUED

Kind of fish used	Diet	Average water temperature degrees F.	Length of experiment in weeks	Initial average length of fish in centimeters	Final average length of fish in centimeters	Percent gain in length	Initial average weight of fish in grams	Final average weight of fish in grams	Percent gain in weight	Initial number of fish in each lot	Percent mortality	Total food fed in grams	Efficiency factor	Pounds of food per pound of fish
Chinook salmon	40% beef spleen 60% seal meal	45	16	3.37	5.03	49	0.48	1.63	240	2,000	2.8	3,290	0.68	1.47
Chinook salmon	30% beef spleen 70% seal meal	45	16	3.37	4.67	39	0.48	1.42	196	2,000	2.3	2,820	0.65	1.54
Sockeye salmon	100% beef liver	60	8	5.60	7.58	35	1.95	6.95	238	450	9.6	5,552	0.34	2.94
Sockeye salmon	100% seal liver	60	4	5.60	6.16	10	1.95	3.36	72	450	32.9	1,970	0.22	4.55
Sockeye salmon	30% beef liver 70% seal meal	60	8	5.60	7.31	31	1.95	6.73	245	450	38.7	2,260	0.58	1.72
Sockeye salmon	30% seal liver 70% seal meal	60	8	5.60	7.17	28	1.95	6.07	211	450	17.6	2,290	0.67	1.49
Silver salmon	100% beef liver	48	24	3.20	7.12	123	0.45	5.43	1,107	2,000	0.4	30,422	0.33	3.03
Silver salmon	60% beef liver 38% Quilcene salmon meal 2% oat flour	48	24	3.20	8.12	154	0.45	7.94	1,664	2,000	0.2	23,162	0.65	1.54
Silver salmon	60% beef liver 36% Quilcene salmon meal 4% oat flour	48	24	3.20	7.99	150	0.45	7.35	1,533	2,000	0.5	22,932	0.60	1.67
Silver salmon	60% beef liver 35.6% Quilcene salmon meal 4.4% oat flour	48	24	3.20	7.98	149	0.45	6.87	1,427	2,000	0.3	23,191	0.55	1.82
Silver salmon	60% beef liver 29% Quilcene salmon meal 11% oat flour	48	24	3.20	7.52	135	0.45	6.42	1,327	2,000	0.4	23,041	0.52	1.92
Silver salmon	60% beef liver 40% Quilcene salmon meal	48	24	3.20	8.12	154	0.45	7.74	1,620	2,000	0.4	24,515	0.59	1.69
Silver salmon	60 parts beef liver 40 parts Quilcene salmon meal 2 parts kelp meal	48	24	3.20	8.13	154	0.45	8.13	1,707	2,000	0.5	25,492	0.60	1.67
Silver salmon	60% beef liver 40% "Salmana"	48	24	3.20	7.17	124	0.45	5.21	1,058	2,000	0.4	26,567	0.36	2.78

TABLE 1—CONTINUED

Kind of fish used	Diet	Average water temperature degrees F.	Length of experiment in weeks	Initial average length of fish in centimeters	Final average length of fish in centimeters	Percent gain in length	Initial average weight of fish in grams	Final average weight of fish in grams	Percent gain in weight	Initial number of fish in each lot	Percent mortality	Total food fed in grams	Efficiency factor	Pounds of food per pound of fish
Silver salmon	100% beef liver	48	12	3.20	5.12	60	0.45	2.35	422	2,000	0.2	10,377	0.36	2.78
Silver salmon	60 parts beef liver 20 parts Quilcene salmon meal 4 parts oat flour	48	12	3.20	5.43	70	0.45	2.55	467	2,000	0.6	8,738	0.48	2.08
Silver salmon	60 parts beef liver 20 parts Quilcene salmon meal 4 parts oat flour cooked with 16 parts water	48	12	3.20	5.31	66	0.45	2.36	424	2,000	0.4	7,545	0.50	2.00
Silver salmon	100% Quilcene salmon meal for first 4 weeks Changed to: 40% beef liver 60% Quilcene salmon meal	48	12	3.20	6.25	95	0.45	4.01	791	2,000	0.1	6,682	1.06	0.94
Silver salmon	40% beef liver 60% Quilcene salmon meal	48	12	3.20	6.31	97	0.45	4.33	862	2,000	0.4	6,926	1.12	0.89
Silver salmon	30% beef liver 70% seal meal	55	10	5.43	7.71	42	2.15	6.94	223	400	10.8	2,625	0.65	1.54
Silver salmon	30% beef liver 70% salmon egg meal	55	10	5.43	7.26	34	2.15	5.75	167	400	18.0	2,605	0.45	2.22
Rainbow trout	100% horse meat	53	26	6.81	12.65	86	3.79	32.89	768	1,300	2.8	142,118	0.26	3.85
Rainbow trout	100% horse meat	53	26	6.81	12.59	85	3.59	29.48	721	1,300	6.9	142,118	0.22	4.55
Rainbow trout	80% cottage cheese 10% chicken eggs 10% horse meat	53	26	6.81	11.42	68	3.51	24.95	611	1,300	10.4	132,622	0.19	5.26
Rainbow trout	80% cottage cheese 20% horse meat	53	26	6.81	11.36	67	3.57	24.66	591	1,300	6.8	132,622	0.19	5.26
Rainbow trout	80% cottage cheese 20% chicken eggs	52	19	6.81	9.69	42	3.60	11.62	223	1,300	8.3	68,558	0.14	7.14
Rainbow trout	100% cottage cheese	51	13	6.81	8.10	19	3.40	6.95	104	1,300	6.0	41,969	0.10	10.00

TABLE 1—CONTINUED

Kind of fish used	Diet	Average water temperature degrees F.	Length of experiment in weeks	Initial average length of fish in centimeters	Final average length of fish in centimeters	Percent gain in length	Initial average weight of fish in grams	Final average weight of fish in grams	Percent gain in weight	Initial number of fish in each lot	Percent mortality	Total food fed in grams	Efficiency factor	Pounds of food per pound of fish
Cutthroat trout	100% horse meat	55	22	8.54	15.23	78	7.10	49.90	603	500	6.8	70,198	0.28	3.57
Cutthroat trout	60% cottage cheese 40% horse meat	55	22	8.54	14.14	67	7.07	43.66	518	500	17.4	66,249	0.23	4.35
Cutthroat trout	80% cottage cheese 20% chicken eggs	55	22	7.90	12.13	54	7.40	21.55	200	500	11.2	50,409	0.12	8.33
Cutthroat trout	100% cottage cheese	50	4	7.83	8.50	9	6.15	7.05	15	500	3.2	5,425	0.08	12.50
Rainbow trout	100% horse meat	59	13	9.73	12.65	30	13.70	32.89	140	1,274	0.8	104,265	0.23	4.35
Rainbow trout	50% horse meat 50% salmon egg meal	59	13	10.23	16.32	60	16.73	78.25	368	500	0.6	96,410	0.32	3.13
Cutthroat trout	50% horse meat 50% salmon egg meal	59	13	10.32	16.67	62	14.88	61.80	315	500	1.4	58,202	0.40	2.50
Rainbow trout	50% horse meat 25% cottage cheese 25% salmon egg meal	59	13	10.39	17.04	64	18.14	79.38	338	500	2.2	96,410	0.31	3.23
Rainbow trout	50% horse meat 25% carp meal (sun dried) 20% cottage cheese 5% chicken eggs	62	10	8.40	13.08	56	10.83	41.96	287	500	0.4	46,753	0.33	3.03
Rainbow trout	50% horse meat 25% "Balto" 20% cottage cheese 5% chicken eggs	62	10	8.40	12.92	54	10.83	36.86	240	500	0.6	46,753	0.28	3.57
Rainbow trout	50% horse meat 10% carp meal (sun dried) 32% cottage cheese 8% chicken eggs	62	10	8.40	12.97	54	10.83	37.99	251	500	0.4	46,753	0.29	3.45
Rainbow trout	100% horse meat	54	18	3.03	5.24	73	0.35	2.90	729	9,538	5.4	89,240	0.26	3.85
Rainbow trout	60% horse meat 40% cottage cheese	54	18	2.31	4.89	112	0.17	2.10	1,135	10,633	18.9	55,803	0.30	3.33

TABLE 1—CONTINUED

Kind of fish used	Diet	Average water temperature degrees F.	Length of experiment in weeks	Initial average length of fish in centimeters	Final average length of fish in centimeters	Percent gain in length	Initial average weight of fish in grams	Final average weight of fish in grams	Percent gain in weight	Initial number of fish in each lot	Percent mortality	Total food fed in grams	Efficiency factor	Pounds of food per pound of fish
Rainbow trout	40% horse meat 60% cottage cheese	54	18	2.28	4.79	110	0.17	2.21	1,200	10,408	18.6	55,803	0.31	3.23
Rainbow trout	60% horse meat 32% cottage cheese 8% chicken eggs	54	18	2.36	4.78	103	0.17	2.12	1,147	10,658	14.3	55,803	0.32	3.13
Rainbow trout	40% horse meat 48% cottage cheese 12% chicken eggs	54	18	2.34	4.70	101	0.17	1.85	988	11,294	24.4	55,803	0.26	3.85
Rainbow trout	75% "Vitamont" (canned horse meat) 25% salmon egg meal	54	9	3.35	4.43	32	0.65	1.47	126	2,000	5.9	10,833	0.14	7.14
Rainbow trout	60% "Vitamont" (canned horse meat) 25% salmon egg meal 12% bran 3% cod liver oil	54	9	3.39	4.36	29	0.68	1.49	119	2,000	7.1	10,833	0.14	7.14
Rainbow trout	70% horse meat 30% salmon egg meal	54	12	2.21	5.16	133	0.17	2.30	1,253	4,000	12.1	19,296	0.39	2.56
Rainbow trout	70% horse meat 30% carp meal (sun dried)	55	9	5.16	6.62	28	2.30	5.25	128	4,000	1.3	27,909	0.42	2.38
Rainbow trout	100% horse liver	55	7	2.28	3.35	47	0.17	0.64	276	4,000	12.4	6,125	0.27	3.70
Rainbow trout	100% "Balto"	55	7	2.28	3.31	45	0.17	0.54	218	4,000	14.4	7,039	0.18	5.56
Rainbow trout	50% horse liver 50% carp meal (sun dried)	55	7	2.28	3.58	57	0.17	0.72	324	4,000	10.5	4,181	0.47	2.13
Cutthroat trout	100% beef liver	52	26	7.30	12.70	74	6.20	28.70	363	57	15.8	3,866	0.28	3.57
Cutthroat trout	100% fresh salted salmon eggs	52	26	7.00	11.90	70	5.90	25.10	325	50	48.0	4,743	0.11	9.09
Cutthroat trout	58% beef liver 42% fresh salted salmon eggs	52	26	6.40	10.90	70	3.70	17.50	373	27	11.1	1,987	0.17	5.88

TABLE 1—CONTINUED

Kind of fish used	Diet	Average water temperature degrees F.	Length of experiment in weeks	Initial average length of fish in centimeters	Final average length of fish in centimeters	Percent gain in length	Initial average weight of fish in grams	Final average weight of fish in grams	Percent gain in weight	Initial number of fish in each lot	Percent mortality	Total food fed in grams	Efficiency factor	Pounds of food per pound of fish
Cutthroat trout	100% beef liver	47	6	3.77	4.55	21	0.96	1.39	45	1,000	4.8	1,815	0.23	4.35
Cutthroat trout	100% frozen seal hearts	47	6	3.77	4.30	14	0.96	1.19	24	1,000	10.4	1,730	0.12	8.33
Cutthroat trout	100% frozen seal meat	47	6	3.77	4.67	24	0.96	1.30	35	1,000	14.5	1,685	0.17	5.88
Rainbow trout	100% beef spleen	53	20	6.45	10.97	70	4.27	20.01	369	300	5.7	21,600	0.21	4.76
Rainbow trout	70% beef spleen 30% seal meal "A"	53	20	6.45	10.81	68	4.31	18.25	323	300	5.7	10,800	0.37	2.70
Rainbow trout	70% beef spleen 30% seal meal "B"	53	20	6.45	10.84	68	4.29	17.51	308	300	2.3	10,800	0.36	2.78
Rainbow trout	70% beef spleen 30% seal meal "H"	53	20	6.45	10.98	70	4.27	17.77	316	300	1.3	10,800	0.37	2.70
Rainbow trout	70% beef spleen 30% "Salmana"	53	20	6.45	10.41	61	4.28	16.21	279	300	4.0	10,800	0.32	3.13
Rainbow trout	70% beef spleen 30% Quilcene salmon meal	53	20	6.45	11.56	79	4.27	20.86	389	300	1.3	10,800	0.45	2.22

FACTORS INVOLVED IN THE SUDDEN MORTALITY OF FISHES

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INTRODUCTION

Since the development of fish culture much difficulty has been experienced because of the sudden and unexpected mortality of fishes. Many descriptions of and comments on this phenomenon have been published (Sewell, 1927, Pruthi, 1932 and 1936, Tomlinson, 1935, Sears, 1936, Hutchinson, 1936). It has been observed that fishes generally start dying just at daybreak. The loss usually is preceded by cloudy weather and a drop in temperature.[1] It is generally believed that under such circumstances the causative factor is shortage of oxygen (Hogan, 1933 and discussion).

Powers (1937) observed dying fish in a holding pond at Kephart Prong Fish Hatchery, Smoky Mountain National Park, and at the Hamblen State Hatchery, near Morristown, Tennessee (Powers and Rostorfer, 1937). In both cases the level of the oxygen was well above that at which fishes can readily absorb this gas from water. At the Kephart Prong Fish Hatchery water in the pond where the fish were dying was normal, except that there was a low CO_2 tension, 0.08 millimeter Hg. The water in another pond in which the fish were doing well was comparable to that in the first pond except that the CO_2 tension was 0.29 millimeter Hg, which was practically in equilibrium with the CO_2 partial pressure of the atmosphere. At the Hamblen State Hatchery the temperature and oxygen content were normal, but the CO_2 tension was 3.00 millimeters Hg. This is about ten times above the point of equilibrium with the CO_2 of the air.

Wiebe (1934) states "... the ponds ... had the lowest CO_2 content at 5:30 A. M., namely 3.9 p. p. m. and 49 per cent." This is far above the low point at which certain fresh water fishes can extract oxygen from water.

Powers (1922) and others have found that fish can absorb oxygen from water at a very low level. Few workers up to the present time have taken CO_2 tension of the water into consideration.

Powers, Rostorfer, Shipe and Rostorfer (1938) have shown that fishes can absorb oxygen to a low level in wide ranges of CO_2 tensions. They found that the rock bass, *Ambloplites rupestris,* can absorb oxygen down to from about 0.40 to 0.30 milliliter per liter at pH 9.75 to 6.10 with the CO_2 tension from about 0.13 to about 21.00+ millimeters Hg; the smallmouth bass, *Micropterus dolomieu,*

[1]The drop in temperature is perhaps incidental. It generally accompanies cloudy weather.

down to about 0.40 to 0.30 milliliter per liter at pH 8.30 to 6.20 ± with the CO_2 tension from about 0.15 to 17.00+ millimeters Hg; and the yellow perch, *Perca flavescens,* down to about 0.35 ± milliliters per liter at pH 8.60 to 6.50 ± with a CO_2 tension from about 0.15 to 14.00+ millimeters Hg.

Experiments and Observations

In the experiments to be described, instead of placing the fish in a closed, airtight bottle filled with water (designated a closed system), an open container was used. In this container part of the fish were held in a trap and kept from coming to the surface of the water while others in the same container were allowed to move freely to the surface of the water. Common blue bream, *Lepomis pallidus,* and rainbow trout, *Salmo irideus,* fingerlings were tested by placing about a dozen fish free in a 10-gallon bottle and the same number in a trap in the same bottle. The trap was a cylinder about 3 inches in diameter and from 10 to 12 inches in length, made of one-fourth inch wire mesh.

Due to the unfortunate use of distilled water in these two sets of experiments the added CO_2 raised the tension far above that found under the most adverse condition in either natural or artificial habitats of fishes. The free bream in each of the four experimental bottles died at about the same rate as the bream confined in traps in the same bottles. The rainbow trout fingerlings lasted longer in the traps than did those which were free in the bottles and able to come to the surface of the water and gulp air. The ratio, though inconclusive, was about 1.00 : 1.03 in favor of the fish that were confined in the traps. However, the CO_2 tensions were far above the level of tolerance as determined by Powers, *et al.* (1938).

In another experiment tap water was used in which the CO_2 tension had been raised to approximately 4.44 millimeters Hg (the water had a pH of 7.05 unaerated and 8.22 aerated). Thirteen fish were placed in a trap and the same number free in a bottle. The fish in the trap lived on an average of 6¼ hours and those in the bottle lived only 3¼ hours. The oxygen content of the water was 5.00 milliliters per liter. The depth of the water in the bottle was about 6 inches. Near the end of one of the experiments all of the free fish except three had died. All looked equally distressed and were moving to the top to gulp air. Two of the fish died shortly after reaching this stage. The third began to remain at the top. This fish showed marked recovery and survived one hour and thirty-one minutes after the last of the other two had died. It had remained at the top for about two hours. Later it swam to the bottom and within from two to three minutes, after several trips to the top, the fish was dead.

In the experiments carried on at the Hamblen State Hatchery, twenty-five fish were placed in each of three open 10-gallon bottles

each containing five gallons of water. This made a depth of about 7.5 inches of water. Three 5-gallon bottles were filled with water, twenty-five fish placed in each bottle, and the bottles stopped air-tight in such a way that air could not leak in and at the same time a uniform pressure could be maintained. None of the water in these experiments was treated.

TABLE 1. RESULTS OF EXPERIMENTS AT HAMBLEN STATE HATCHERY IN WHICH THE TEMPERATURE OF THE WATER WAS NOT CONTROLLED

		pH of experimental water					
System[1]	Number of fish	pH at end	pH aeration	pH difference	CO_2 tension in millimeters Hg at end	Oxygen in milliliters per liter at end	Death rate of fish (number of fish per hour)
Closed	25	7.13	8.40	1.27	5.61	1.53	6.24
Closed	25	7.13	8.39	1.26	4.89	1.49	6.22
Closed	25	7.13	8.32	1.19	4.65	1.53	7.29
Open	25	7.33	8.42	1.09	3.72	2.18	6.57
Open	25	7.37	8.38	1.01	3.09	1.89	6.57
Open	25	7.33	8.40	1.07	3.64	2.08	6.59

[1]Closed systems comprised 5-gallon bottles filled with water in such a way that air could not enter but still a uniform pressure could be maintained. Open systems comprised 10-gallon bottles containing only five gallons of water.

It was found (Table 1) that the fish which were not allowed to gulp air reduced the oxygen to a lower level at a higher CO_2 tension than did those in the open bottle, where they could gulp air. Averages for the closed bottles were, oxygen 1.52 milliliters per liter and CO_2 tension 5.04 millimeters Hg, and for the open bottles 2.05 milliliters per liter oxygen and 3.78 millimeters Hg in CO_2 tension. The death rate was nearly the same, averaging eight hours and twenty minutes per fish in the closed bottles and eight hours and twenty-six minutes in the open bottles. Not all of the fish in the open bottles had died at the time the experiments were ended. The experiments were discontinued, since the number of fish in relation to the amount of water was small as compared with the number at the beginning of the experiment. The smaller number of fish would tend to agitate the water more in proportion than the larger number at the beginning of the experiment. This would allow the water to take up more oxygen than was being removed, and more CO_2 would be given off from the water than given to it by the fish. One fish was alive in Experiment 3, 11 in Experiment 4, 5 in Experiment 5, and 10 in Experiment 6, when the experiments were terminated.

The experiments indicate that when a fish rises to the surface and gulps air in water with a high CO_2 tension, it is at a disadvantage physiologically. Unfortunately, the temperature in the experiments ran up to 22° C., which is a little high for rainbow trout.

In another set of experiments at Hamblen State Hatchery, twenty-six fish were placed in each bottle containing five gallons of water. The temperature was held at approximately 16° C. CO_2 was added to the waters of the two open 10-gallon bottles, Nos. 2 and 3, in order to keep the CO_2 tension of the water in the open and closed bottles comparable. In each of the open bottles thirteen fish were placed in a trap at the bottom and thirteen were left free to gulp air. The fish in the closed bottle with a CO_2 tension of 7.48 millimeters Hg absorbed oxygen down to 1.06 milliliters per liter before dying (Table 2). In bottle No. 3, with a CO_2 tension of 8.10 millimeters Hg, the fish absorbed oxygen down to 1.59 milliliters per liter and in bottle No. 2 down to 1.66 milliliters per liter at a CO_2 tension of 11.43 millimeters Hg. The rates of dying in bottle No. 2 were the reverse of those in bottle No. 3. The rate in the trap was 6.07 and in the bottle 5.48.

This set of experiments indicates that it is advantageous for fish to break water (come to the surface and gulp air) at low oxygen tensions provided the CO_2 tension is not too high.

TABLE 2. RESULTS OF EXPERIMENTS AT HAMBLEN STATE HATCHERY IN WHICH THE TEMPERATURE OF THE WATER WAS MAINTAINED AT APPROXIMATELY 16° C.

Bottle No.	System[1]	Number of fish	Fish retained in	Per cent of fish died with mouth: open	Per cent of fish died with mouth: closed	pH of experimental water: pH at end	pH of experimental water: pH aerated at end	pH of experimental water: pH difference	CO_2 tension in millimeters Hg at end	Oxygen in milliliters per liter at end	Death rate of fish (number of fish per hour)
1	Closed	26	Bottle	88	12	7.04	8.40	+1.34	7.48	1.06	5.14
3	Open	13	Bottle	55	45	7.16	8.58	+1.43	8.10	1.59	6.12
		13	Trap	61	39	-----	-----	-----	-----	-----	6.05
2	Open	13	Bottle	27	73	6.80	8.38	+1.58	11.43	1.66	5.48
		13	Trap	39	61	-----	-----	-----	-----	-----	6.07

[1]The closed system comprised a 5-gallon bottle filled with water and stoppered so that air could not enter but still a uniform pressure could be maintained. The open systems comprised 10-gallon open bottles containing only five gallons of water.

At the end of the experiments it was found that some of the fish died gasping and that others did not. It has long been known that gasping is a symptom of asphyxiation. The relative number of fish that died gasping and those that did not was determined. The ratios are tabulated in Table 2: No. 1, a closed bottle, CO_2 tension 7.48 millimeters Hg, 88 to 12 per cent; No. 3, an open bottle, CO_2 tension 8.10 millimeters Hg, 61 to 39 per cent in the trap and 55 to 45 per cent in the bottle; No. 2, an open bottle, CO_2 tension 11.43 millimeters Hg, 39 to 61 per cent in the trap and 27 to 73 per cent in the bottle.

It may be pointed out here that free fish in the bottle, when

swimming to the surface of the water, would force the partly aerated water downward over the fish in the traps. This agitation of the water would have the same, although a milder, physiological effect on the fish in the traps as the swimming to the surface and the gulping of air.

The experiments again point to an ill effect, other than asphyxiation, on fish coming to the top and gulping air when the CO_2 tension of the water is high. By high is meant the CO_2 tension brought about by fish when they have absorbed the oxygen of the water down to a low level in a closed system. In this set of experiments the CO_2 tension thus formed in the water of the Hamblen State Hatchery is shown by bottle No. 1 (a closed system). The CO_2 tension of the water at the beginning of the experiment was 2.85 millimeters Hg (unaerated water pH 7.35 and aerated water pH 8.33), and was 7.48 millimeters Hg at the end of the experiment. Hence 7.48 millimeters Hg would be the CO_2 tension of the water at the Hamblen State Hatchery when fish are retained in a closed system and allowed to lower the oxygen content down to 1.06 milliliters per liter. The CO_2 tension was increased 4.63 millimeters Hg. This agrees very closely with theory.

Powers, *et al.* (1938) found that freshwater fishes are able to absorb oxygen to low levels through a wider range of CO_2 tensions than found in natural waters in which they live; that the pH of the blood is fairly constant for each species over a wide range of CO_2 tension of the water; that the CO_2 tension of the venous blood is determined by the CO_2 tension of the water plus the metabolic carbon dioxide; and that the constancy in the acidity of the blood is maintained at different CO_2 tensions by increasing or decreasing the alkaline reserve of the blood. In other words, the CO_2 tension of the water brings about profound changes in the blood of freshwater fishes. On the other hand, these fishes were able to extract oxygen from the water down to a low level before dying or even showing distress.

Davidson (1933) reported fishes dying with only a moderate rise in CO_2 tension when oxygen was not reduced to a low level. Powers (1937) observed fish dying in water, at Kephart Prong Hatchery, having a temperature of 13° to 17° C., CO_2 tension of 0.08 millimeter Hg and an oxygen content of 6.30 milliliters per liter. At Hamblen State Hatchery, on February 25, 1937, fish died in water at 12° C. which had a CO_2 tension of 2.38 millimeters Hg and an oxygen content of 6.22 milliliters per liter. Two days later fish were observed dying at the hatchery with water at 13° C., oxygen content 6.68 milliliters per liter and CO_2 tension 3.00 millimeters Hg (Powers and Rostorfer, 1937).

Fish cannot maintain the CO_2 tension of their blood at a uniform level under different CO_2 tensions of the water. On the other hand, the CO_2 tension of the blood parallels very closely the tension

of the water. The pH of blood is fairly constant under wide variations of CO_2 tensions. This uniformity is maintained by fish changing the alkaline reserve of the blood. The rapidity with which the alkaline reserve of the blood is modified is not known. It must be fairly rapid at least for small changes in CO_2 tension. If not, fish could not move rapidly up streams and choose either of two forks of a river. The two forks often vary in their CO_2 tensions (Powers and Hickman, 1928; Powers, 1928). In experiments with high and also very low CO_2 tensions (Powers, *et al.*, 1938) fish when placed in the water would often become sick and appear to be dying. After some minutes they would resume a normal appearance. These same fish after recovering would continue to absorb oxygen down to low levels. From this it would seem that the adjustment of their blood to a higher or lower CO_2 tension of the water is not instantaneous.

The observations and experiments show three things, namely: (1) a fish can adjust itself to wide ranges of CO_2 tensions of the water, provided the change is not too sudden; (2) the adjustment is not instantaneous; and (3) a fish can apparently remain normal in water of high or low CO_2 tension within limits, provided the oxygen tension is not too low. When the oxygen is low asphyxiation results. This is true if a fish remains in a closed system.

Discussion

During the night, fishes do not come to the surface of the water, and are thus in a closed system.[2] So long as a fish remains beneath the surface (in a closed system) it can apparently live in water with an abnormal CO_2 tension with little ill effect, provided the oxygen supply is adequate. Fish come to the surface of the water in the early morning and gulp air, with a CO_2 partial pressure of about 0.30 millimeters Hg, or bathe their gills with water of approximately this CO_2 tension. Their blood tends to become adjusted to this tension. They then drop down below the surface, and if, for any reason, the water has a higher or lower CO_2 tension the blood must be readjusted to that tension. The fish soon become deranged through compensating at short intervals for different CO_2 tensions. Heavy feeding aggravates the situation by removing hydrochloric acid from the blood which in turn requires an adjustment. This is aside from an increase in the CO_2 tension through food contamination. When the fish are crowded their metabolic carbon dioxide could raise the CO_2 tension of the water sufficiently high to distress the fish gulping air at intervals. At the Hamblen State Hatchery rainbow trout exhibited distress when the CO_2 tension of the water was only 3.00 millimeters Hg. Rainbow trout at this same hatchery

[2]Information concerning the behavior of young bass and trout was obtained from independent statements made by two experienced hatchery superintendents, Mr. W. T. Ivy, Hamblen State Hatchery, Morristown, Tennessee, and Mr. John C. Sullivan, Bucyrus Fish Hatchery, Bucyrus, Ohio.

raised the CO_2 tension in the water through 4.82 millimeters Hg by the time they were asphyxiated by low oxygen in a water-filled stoppered bottle (a closed system). If for any reason the CO_2 tension is above normal, the crowded fish could easily raise the CO_2 tension to 3.00 millimeters Hg without lowering the oxygen to the limit of tolerance.

Fishes die at and following daybreak, not because of a shortage of oxygen, but because of a derangement brought about by the blood compensating first for a high and then a low CO_2 tension in the water. This alternation of compensation is started by the fish coming to the surface to feed at daybreak, when the CO_2 tension in the water is abnormally high. Thus fish die, not by asphyxiation, but by derangement when exposed alternately to higher and lower CO_2 tensions in water. This is shown by the fish confined in the traps in the open bottle experiments which were deranged by the constant stirring of the water in the bottles. The water was from 6 to 7 inches in depth. The partly aerated water at the surface was washed over the fish in the traps by other fish swimming to the surface.

Despite the fact that CO_2 tension seems to be the aggravating factor in the two observations in fish mortalities at Kephart Prong Hatchery and Hamblen State Hatchery, other factors may probably bring about a sudden mortality of fishes. A toxic substance or lack of oxygen might be a determining factor. Tomlinson (1935) reported an instance when some 400,000 fish were lost. He stated, "Even the eels and crayfish crawled out on the bank to die." As suggested, lack of oxygen must have been a factor. The incident might have been brought about by bacteria. The fishes alone could not have reduced the oxygen to barely a trace, as was reported by Tomlinson, before having died from deranged alkaline reserve of the blood. The statement by Tomlinson (*op. cit.*), that "At the time of the catastrophe the pond had been 'working' for several days, while a few days before there had been severe rains, accompanied by abrupt change in temperature," suggests a possibility that bacteria might have been washed into the pond and setting up the following described situation. The fall of temperature likely is incidental and not a direct factor.

On three occasions the author met with an interesting situation that might throw light on the above statements. In 1922 water was taken from a well in the "Lowlands" of Arkansas across the river from Memphis, Tennessee. This water was alkaline when aerated, as would be expected of waters of this region. On aeration it was above pH 8.00 with phenol red. In a few seconds on completion of aeration the water would change back to acid below the phenol red range. This was repeated a number of times with a single sample of water. At that time this was considered only as a very interesting phenomenon.

In 1926, when water was being aerated to determine the interrelation between CO_2 tension and the pH of the water, this same phenomenon was observed in one of the samples. The water from which the sample was taken was set aside for further study. The next day the phenomenon could not be repeated.

During the summer of 1935 at the Franz Theodore Stone Laboratory, Put-in-Bay, Ohio, a test tube of our experimental water had been allowed to set over night. The pH of this water was below the phenol red range. It was aerated and the pH came back to above 8.00, which was normal. In a few seconds it had changed back to acid below the phenol red range. For my own satisfaction I aerated the sample three or four times. I repeated the performance two or three times for my colleagues. This small sample of less than 5 milliliters had changed from alkaline to acid more than a dozen times in less than twenty minutes. No other water in the laboratory was found to have this characteristic. Due to the lack of proper equipment and materials and the small amount of water, less than 5 milliliters, the behavior of the oxygen in solution and the presence of bacteria were not determined. The acid or acids formed were either volatile or reversible. There was enough material in the water for the bacteria, if present, to repeat the performance at least a dozen times.

I describe the above phenomena in order to caution others that the tests for the presence of bacteria in the behavior of the oxygen in solution should not be overlooked. Such phenomena would play havoc with fish in a rearing pond.

Generally, when water is deoxygenated, CO_2 is added to the water. This in turn raises the CO_2 tension of the water. Fortunately the CO_2 tension is not raised as rapidly as the tension of oxygen is lowered. This is due to the difference in the coefficients of absorption of the two gases, oxygen 0.0289 and CO_2 0.759 at 25° C. in distilled water. This is a marked adaptation of the environment. The oxygen tension of the water when in equilibrium with the oxygen partial pressure of the atmosphere (21 per cent) is 159+ millimeters Hg. If it were not for the very high coefficient of absorption of CO_2 fish would destroy themselves with their own carbon dioxide excreted through their respiration. Crowded fish do bring about a condition adverse to themselves. The rainbow trout in the experiments carried on at the Hamblen Hatchery raised the CO_2 tension in the water from 1.36 to 6.90 millimeters Hg through 5.54 millimeters Hg of tension before dying of asphyxiation in a closed system.

Trying to carry too many fish in a volume of water brings about difficulties. Fishes destroy themselves by their own metabolic carbon dioxide. This could not occur in nature except during migratory movements, and this has not been known to occur. Davidson

(1933) cites a possible instance, but this was due perhaps to factors other than crowding.

Since the work described above was completed, man, through his modifications of nature, has furnished in Norris Lake a most excellent laboratory experiment. Instead of 10-gallon open bottles with water a few inches in depth, we have a basin of over a cubic mile of water with the greatest depth of over 200 feet and an exposed surface of over 53 square miles containing various species and sizes of freshwater fishes.

The level of the lake was lowered approximately 0.7 feet per day from November 6 to January 10. The lowered level was 41.2 feet. At the same time the water level was being lowered two large rivers, the Clinch and the Powell, and other streams were filling the lake with waters of temperatures at times as low as 0° C. By the two factors, (1) a rapid emptying of the water from the bottom, and finally both from the top and bottom and (2) the filling with water of a lower temperature, the waters of the lake were so mixed that there was a marked difference between the CO_2 tension of the water at the surface and the CO_2 partial pressure of the air (Powers, Shields and Hickman, MS). As a result the gizzard shad, ***Dorosoma cepedianum***, a surface and near surface fish, died by the millions. The small shad died first where the waters were first disturbed, i.e., near the mouths of the large rivers. They started dying later where the water was last to be disturbed by the colder water pushing up all other waters. This occurred near the dam and in the smaller stream basins where the volume of water was large in proportion to the stream inflow. At first only the smallest shad died, with occasional larger ones and less occasionally other species of fishes. At the end of the epidemic the dead fish comprised the larger shad and a few larger fishes. The smaller shad ceased dying, or all were dead, by the time the streams had warmed up and well aerated water began flowing on the surface. At this time the dying fish were predominantly shad of larger size. The waters at the surface with higher CO_2 tension were pushed below by inflowing well-aerated warmer river waters. There was then formed a narrow thermocline not far below the surface. At a locality where larger size shad were found dying the upper limit of the thermocline was not lower than 20 feet below the surface. Thus a fish migrating vertically at moderate differences of levels at 20 feet and below would meet with marked differences in CO_2 tensions. Fish would undergo the same derangements as fish coming to the surface and gulping air when there is a certain minimum difference between the CO_2 tension of the water and the CO_2 partial pressure of the air. At this place all fish freshly dead or dying had bloated air bladders, which suggests that these fish were not surface fish when they became deranged. At no place during the above observations was the water found greatly deficient in oxygen.

This report has been made with the hope that more judicious selections can be made for locating rearing ponds, hatcheries, etc., and that sudden mortalities can be predicted and prevented.

Acknowledgments

I wish to thank Mr. E. L. Thomas for his courtesy in allowing me free access to Andrew Jackson Lake. Thanks are also due to Mr. W. T. Ivy, Superintendent, Hamblen State Hatchery, for furnishing me with rainbow trout, and to Mr. Robert Clark for assisting in the experiments.

Summary

1. Sudden mortality of fishes is generally brought about by abnormally high CO_2 tension of the water.

2. Death is not caused by asphyxiation but by a derangement brought about by alternate compensation of the blood to higher and then to lower CO_2 tension of the water.

3. The mortality occurs most frequently at daybreak when fish come to the surface and break water. This initiates the alternate compensation of the blood to higher and lower CO_2 tension when the CO_2 tension of the water is abnormally high.

4. During the night fishes hover near the bottom and can survive without difficulty in the abnormally high CO_2 tension water since there is no alternating compensation of the blood to differences in CO_2 tension.

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THE UNDEVELOPED FISHERIES RESOURCES OF LOWER CALIFORNIA

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After the many suggestions made on sundry occasions by newspapermen, representatives of agricultural and industrial enterprises, and business men for the exploitation of the natural resources of Lower California, and after due analysis of those sources of wealth, the conclusion has been reached that the future of this Province lies in its seas. Experienced voices thus proclaim it. How could it be otherwise, since the fish caught annually by American and Japanese fishing boats amounts to the enormous sum of ten million pesos?

A territory like Lower California, which possesses immense wealth and whose extensive shores, bordering on two seas, offer prospects rich in economic possibilities for better living, justifies our careful study of the peninsula, inasmuch as reliable data show that fish are abundant here. The many varieties of different fishes are of excellent quality and food value, and have exquisite flavor. They are valuable not only for immediate consumption but for different pickled and salted preparations. If to this we add, that consumption today is considerable, notwithstanding the high prices in the interior of the Republic, it must be agreed that when the marine wealth of that section is exploited, it will be possible to satisfy the general needs of the country. Prosperity and social welfare will prevail among the working classes of the territory if the Californians practice fishing as recommended by us, for there is no reason why this should not be so. Therefore, it is imperative that the Government of Mexico, through laws, start the territory on the path of production and prosperity.

No one is ignorant of the fact that capital is required for such fishing operations, and that in Lower California it is not to be found. Surely Mexican fishermen, once well trained from the technical standpoint, and properly organized under adequate direction, will be able to compete, as fishermen, with those of any other nationality. Therefore, the human element for large scale fishing in Lower California does exist; capital, technique, and proper organization are lacking.

The establishment of an enterprise possessing all these elements for successful operation is required. Direct and efficient protection by the state is needed, as was found in Spain at the beginning of this century.

Though it may seem strange, the fish-canning industry in Spain is of recent origin. In a short time it has attained such growth and importance that fishing wealth and operations constitute an outstanding item among the many sources of wealth available in the

peninsula. What is more significant, the fishing industry, that for so many years remained stationary, acquired unusual importance with the introduction of pickling and salting methods. Spain today, ranks with Japan as one of the foremost countries in the fishing industry of the world, not only on account of her production but because of her up-to-date and large fleet. It is interesting to note that statistics register the fabulous sum of *one hundred million tons* as the amount of Spain's annual sardine catch, which means a value of *eighty million pesetas* at ports of landing; that is, it is valued, at this sum in the ports and as fresh fish. These data afford some idea of the great importance that the industry in question has attained in Spain. We do not deem it necessary to point out that the foregoing statistics are of unimpeachable authenticity. If to this we add, the flourishing prosperity enjoyed by industries connected with the fisheries, such as, the tin plate, soldering, lead, lumber for boxes, oil, salt, transportation, and shipbuilding industries, etc., etc., it will be observed that the number of men employed is enormous, so that we must agree that the part this industry plays in the economic life of the country is truly staggering.

The fish-canning industry at first began on a very small scale, supplying only the domestic market, but soon its activities extended to foreign markets, which today comprise several nations, including Mexico which is one of the leading consumers. There are firms in Spain, such as Curbera at Vigo, "La Pesquera del Norte" at La Coruña, Herrero Hermanos at Candas, "Albo" at Santoño, "Goenaga" at Ondarroa, "Garavilla" at Lequeitio, and "Jose Serratos" at Bermeo, whose plants turn out a number of preparations of fish which compete favorably with similar brands of other nations. Their products are not sufficient to supply the innumerable orders received from different sources, notwithstanding the fact that production attains incredible totals. One of the firms referred to states in its advertisements, "We turn out *one hundred thousand cans a day* when in production." By "in production" must be understood the fishing season, for we must not forget that there are many migratory species of fish.

We grant that Spanish fish is delicious and even that "it possesses an unmistakable flavor" as Spanish canners say in their advertisements, but many of the Mexican fishes could compete with Spanish fish. It is to be regretted that through the apathy of some and the indifference of others, greater attention is not devoted to the preparation of Mexican fish, thus depriving the Mexican market of said products. For example, what difference is there between the "robalo" or "llobaro" (equal to the Spanish "lubina" that fetches top prices in the Spanish markets) and the Spanish "merluza" or hake? What difference is there between our red snapper or braize and the Spanish "ollomón" or red gilthead which belongs to the species *Pangelus controdintus?* What is the difference between the

"tunny" (called "tuna" by the Americans) and the Spanish "striped tunny"? Do they not all belong to the "Escondrido" group of the order Acanthopteri? This fish abounds off the western shores of Lower California especially near Cape San Lucas. It is exported chiefly to the United States, where large quantities are packed. Mexican waters produce annually over *two thousand tons.* Thus we could compare our "mojarra" with the "parpardo," the "jurel" with the "chicharro," the "cherna" with deep sea bass, the 'barbel' with perch, the ray with mullet, the "totoaba" with skate, etc., including also the sawfish and the sardine that in certain periods of the year are to be found in abundance in Mexican waters. In France, sawfish are called "maquereaux," in Spain "verdel." So great is the demand in France for this fish fresh, that from the nearby Spanish ports, such as Fuenterrabía, Guetaria, Ondarroa, Lequeitio, Elanchove, Bermeo, etc., great quantities are taken. This sawfish prepared in a natural state and packed in oil is extraordinarily delicious, because of its purity of flavor. Put up in different styles it would be appreciated in our own market, there is no doubt, but at present it is used only in ordinary home-cooking.

And lastly, what can we say of our Pacific sardine? Is it not just as exquisite as the Spanish sardine? Or are we to admit that Spain possesses the best sardine in the world, as Spanish canners are wont to say? Certainly not. I am in a position to assert and prove that Mexican sardines, caught in the Pacific, are as good and as tasty as Spanish.

From the foregoing, and for other reasons that I do not mention for fear of unduly lengthening this report, it may be inferred that there is little or no difference between the food value of our fishes and the species produced by other countries. It is said that repetition is the only thing that produces results in this life; therefore, I repeat—Mexican fish is mostly as good as the Spanish. Now, if this is true with respect to its quality it can also compete advantageously in price. What are we to do? Sit back and continue to live in the twentieth century as in biblical days when the rod of Aaron flourished, manna fell from heaven at Moses' bidding, and in Canaan loaves and fishes were multiplied? Of course not. In our opinion there is but one thing to do; to face reality and try to discover the causes of the lack of progress, for once these are known they will be easy to remedy, the more so at present, when our straightforward President, a man sound in body and in mind and universally praised, is endeavoring to bring into play all the great resources of the nation, to open up new sources of wealth, which we believe is imperative. As the opportunity is excellent, we must devote ourselves seriously to this matter. Will it fall to the share of this austere man to lay the foundation of the industry of which we

speak? Surely, because our worthy President, Mr. Cardenas, is a man who faces facts, a man of action.

From the foregoing fundamental reasons and data it may clearly be seen (Spain's progress in this field explains clearly the reasons) how important exploitation of the fishing industry is to Mexico, for though it is true that a packing plant already exists, this plant is not specialized. Thus we gather that it is high time that men of good will think over and study this problem, inasmuch as a new industry would be added to the already flourishing Mexican commerce.

If there are any doubts aroused by the perusal of this paper, my desire to collaborate in the establishment of the fishing industry and to advance the prosperity and improvement of Mexico lead me to place myself at the disposal of any one who may require my services in regard to any explanations that may be needed, with the assurance that my ample experience in the fishing industry will permit me to clear away any doubts and uncertainties. An experience acquired over a period of fifteen years of practical work in one of the plants at Bermeo (Biscay), the biggest port in Northern Spain, as technical head places me in a position to speak in the terms I have used above.

Having set forth the foregoing at length, I shall bring this report to a close by stating that if the exploitation of the fishing, canning, and salting industry is carried on by honest and experienced men, Mexico could in a comparatively short time become an exporting instead of an importing country. That, in our opinion is the place that is rightfully Mexico's.

APPENDIX

AMERICAN FISHERIES SOCIETY
Organized 1870

CERTIFICATE OF INCORPORATION

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certifying in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interest of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

SEYMOUR BOWER	(Seal)
THEODORE GILL	(Seal)
WILLIAM E. MEEHAN	(Seal)
THEODORE S. PALMER	(Seal)
BERTRAND H. ROBERTS	(Seal)
HUGH M. SMITH	(Seal)
RICHARD SYLVESTER	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

OF THE

AMERICAN FISHERIES SOCIETY

(As amended September 4, 1936)

ARTICLE I

Name and Object

The name of this Society shall be American Fisheries Society.

The objects of this Society shall be to promote the cause of fish culture and its allied interests; to gather and diffuse information on all questions pertaining to fish culture, fish, and fisheries; and to unite and encourage those interested in fish culture, and fisheries problems.

ARTICLE II

Membership

The membership of this Society shall be classified as follows: Active, Club, Libraries, State, Patron, Honorary, and Corresponding.

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society. The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. Any active member may upon payment of fifty ($50.00) dollars become exempt from the payment of annual dues though retaining the privileges of active membership for the duration of his life.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries.—Libraries may be admitted to membership upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for libraries shall be two ($2.00) dollars per year.

State Memberships.—Any state, provincial or federal department of the United States, Canada or Mexico may become a state member of this Society upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for State memberships shall be twenty ($20.00) dollars per year.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member of this Society upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President of the United States, the Governors of the several states, and the Secretary of Commerce of the United States, the Governor-General of Canada, the Lieutenant-

Governors of the several Canadian provinces, and the Dominion Minister in Charge of Game and Fisheries shall be honorary members of this Society while occupying their respective official positions.

Election of Members between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized to act upon all applications for memberships received while the Society is not in session.

Rights and Duties of Members.—Active members in good standing only shall have the right to vote at regular or special meetings of the Society. Any member is held to be in good standing whose dues are not more than one year past due. In case of non-payment of dues for one year, proper notice shall be given the member by the Treasurer in writing, and if such member remains delinquent one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of one year, except upon payment of arrears and current dues. Each member of the Society in good standing, except honorary members, shall receive one copy of the annual volume of Transactions.

Quorum.—Twenty voting members shall constitute a quorum for the transaction of business at annual or other meetings of the Society.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a president, a first vice-president, and a second vice-president, all of whom shall be elected for the term of one year and shall be ineligible for reelection to the same office until a year after the expiration of their terms; a secretary, a treasurer, a librarian, and five vice-presidents, one to be in charge of each of the following divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

The officers specified above, and the president of the previous year, shall form

an Executive Committee* with authority to decide the policies of the Society and to transact such business of the Society as may be found necessary. The Executive Committee is authorized to fill from the membership any vacancies that may occur in any offices between meetings. A majority of the Executive Committee shall constitute a quorum.

Only members in good standing who are in attendance or have been in attendance at one of the two immediately preceding meetings shall be eligible for election to the offices listed above and for appointment to any committee, except the members of the Committee on Common and Scientific Names of Fishes.

The officers shall be elected by a majority vote at a regular meeting, a quorum being present.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the regular and all special meetings of the Society and shall be ex-officio chairman of the Executive Committee.

The first Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, conduct its correspondence, promote its membership, and arrange for regular and special meetings. The Secretary shall also attend to the publication and distribution of the annual issuance of Transactions.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of seven thousand, five hundred ($7,500) dollars to be approved by the Executive Committee and to be paid for by the Society. The offices of Secretary and Treasurer may be occupied by the same person.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions.

The Vice-President of each division shall become conversant with the subject of his division and present a report on it at the regular meeting placing emphasis upon developments during the past year.

Committee members shall cooperate in performing the functions of their appointments and render reports as directed by the President.

ARTICLE V

Standing Committees

The standing committees shall be Executive; Foreign Relations; Common and Scientific Names of Fishes; and Publications. The Committee on Publications shall be appointed by the President. The Executive Committee shall be selected as provided for by article IV.

The Committee on Foreign Relations shall be composed of seven members selected by the nominating committee for election, and its duties shall be to exchange ideas pertaining to the various phases of fisheries administration, biology, including fish culture, with foreign fisheries biologists, conservation and fisheries administration officials, fish culturists or aquicultural societies. A report based on such exchange should be presented at each regular meeting.

The Committee on Common and Scientific Names for Fishes shall be composed of seven members selected by the nominating committee for election. Its duties shall be to establish and maintain in the files of the Librarian of this Society a

*The Council was discontinued and the Executive Committee enlarged by Amendment to By-Laws, September 11, 1935.

correct check list of the species of fishes occurring in the waters of the United States and Canada. This list should contain both scientific and common names.

The Committee on Publications shall be composed of five members, and its duties shall be to select and edit manuscripts submitted for publication. Papers shall be submitted ready for publication within thirty days after the close of the regular meeting. Such papers, together with the minutes of the regular and special meetings and the reports of the various divisions and committees, shall be published in an annual volume which shall be numbered in series with previous volumes and entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY.

ARTICLE VI

Meetings

The regular meeting of the Society shall be held once a year, the time and place to be decided upon at the preceding meeting, or, in default of such action, by the Executive Committee. Special meetings shall be called by the President upon approval of a majority of the Executive Committee.

ARTICLE VII

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Application for memberships.
4. Reports of officers:
   a. President
   b. Secretary
   c. Treasurer
   d. Vice-Presidents of Divisions
   e. Standing Committees
   f. Special Committees
5. Committees appointed by the President:
   a. Committee of five on nomination of officers and standing committees for the ensuing year.
   b. Committee of five on time and place of next meeting.
   c. Committee of five on resolutions.
   d. Auditing committee of three.
   e. Committee of three on program.
   f. Committee of three on publicity.
   g. Committee of five on publications.*
6. Reading of papers and discussions of same. In the reading of papers preference shall be given to the members present.
7. Miscellaneous business.
8. Adjournment.

ARTICLE VIII

Changing By-Laws

The By-Laws of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least twenty-five members are present at said regular meeting.

*A resolution adopted August 24, 1937 established a staggered committee of five and provided that each succeeding President shall appoint one new member for a term of five years and designate the Chairman of the Committee.

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS
(Showing Year of Election to Membership)

HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
Governor-General of Canada.
Lieutenant-Governors of the several Canadian Provinces.
Dominion Minister in Charge of Game and Fisheries.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'04 Denbigh, Lord, London, England.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 California Barrell Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore & Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co., C. W. Weld, Mgr., 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3d St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The, W. A. Barbour, Mgr., 443 Mission St., San Francisco, Calif.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware & Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Pope and Talbot, Foot of 3d St., San Francisco, Calif.
'15 Puget Sound Navigation Co., Seattle, Wash.

'15 Ray, W. S. Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California, James B. Brady, Gen. Mgr., 2nd and Folsom Sts., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

'12 Barnes, Ernest, Fisheries Experiment Station, Wickford, R. I.
'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wis.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'11 Cleveland, W. B., Burton, Ohio.
'04 Coker, Dr. Robert E., University of North Carolina, Chapel Hill, N. C.
'01 Dean, Herbert D., Northville, Mich.
'15 Folger, J. A., Howard and Spencer Sts., San Francisco, Calif.
'12 Fortmann, Henry F., 1007 Gough St., San Francisco, Calif.
'26 Goelet, Robert W., 18 East 47th St., New York, N. Y.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George M., Marine Biological Laboratory, Woods Hole, Mass.
'23 Grey, Zane, Altadena, Calif.
'28 Hall, W. A., Co., Gardiner, Mont.
'10 Hopper, George L., Havre De Grace, Md.
'23 Kienbusch, C. O., 12 E. 74th St., New York, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 So. Ann St., Mobile, Ala.
'23 Lloyd-Smith, Wilton, 63 Wall St., New York, N. Y.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
'15 Mailliard, Joseph, 1815 Vallejo St., San Francisco, Calif.
'99 Morton, W. P., 105 Sterling Ave., Providence, R. I.
'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205 8th St., N. W., Washington, D. C.
'31 Nicholas, E. Mithoff, 20 S. 3d St., Columbus, Ohio.
'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
'04 Palmer, Dr. Theodore S., 1939 Biltmore St., N. W., Washington, D. C.
'10 Radcliffe, Dr. Lewis, 5600 32nd St., N. W., Washington, D. C.
'05 Safford, W. H., 229 Wing St., S., Northville, Mich.
'00 Thompson, W. T., 121 N. Willson, Bozeman, Mont.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'12 Townsend, Dr. Charles H., New York Aquarium, New York, N. Y.
'11 Valette, Luciano H., Echevarria F. C. S., Buenos Aires, Argentina, S. A.
'22 Walcott, Frederic C., State Office Bldg., Hartford, Conn.
'98 Ward, Dr. Henry B., 1201 W. Nevada St., Urbana, Ill.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

ACTIVE MEMBERS

'16 Adams, Dr. Charles C., State Museum, University of the State of New York, Albany, N. Y.
'35 Adams, Harry E., U. S. Forest Service, Milwaukee, Wis.
'33 Adams, Milton P., 638 Sunset Lane, East Lansing, Mich.
'13 Adams, William C., Dept. of Conservation, Albany, N. Y.
'29 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'33 Aitken, W. W., Des Moines, Iowa.
'33 Albert, W. E., Jr., Lansing, Iowa.
'31 Aldrich, A. D., 2879 East Archer, Tulsa, Okla.
'34 Alexander, George J., Parliament Bldgs., Victoria, B. C., Canada.
'36 Allen, Edward W., Northern Life Tower, Seattle, Wash.
'35 Allen, George W., Stevens Point, Wis.
'29 Allen, William Ray, Dept. of Zoology, University of Kentucky, Lexington, Ky.
'32 Allen, Dr. William S., P. O. Box 7, Sherbrooke, P. Q., Canada.
'34 Allers, Charles J., 804 Union St., Traverse City, Mich.
'26 Alm, Dr. Gunnar, Commissioner of Freshwater Fisheries, Lantbruksstyrelsen, Stockholm, Sweden.
'33 Anderson, Albin, 376 E. Maryland St., St. Paul, Minn.
'08 Anderson, August J., Box 704, Marquette, Mich.
'35 Anderson, Herman, Route 1, Iesaquah, Wash.
'33 Anderson, Wendell A., Woodruff, Wis.
'35 Anderson, William H., 13 Pine St., College Heights, Hyattsville, Md.
'35 Andrews, A. E., 405 State Library Bldg., Indianapolis, Ind.
'24 Annin, Harry K., Spring Street, Caledonia, N. Y.
'14 Annin, Howard, Van Cortland Ave., Ossining, N. Y.
'37 Atkinson, Clinton E., Westminster Trust Bldg., New Westminster, B. C., Canada.
'29 Atkinson, C. J., Fisheries Dept., Ottawa, Ont., Canada.
'36 Atwood, Earl L., New Federal Bldg., St. Louis, Mo.
'36 Babcock, James A., Lake Wapello, Drakesville, Iowa.
'32 Baer, Harry D., U. S. Fisheries Station, Quinalt, Wash.
'36 Bailey, Reeve M., Dept. of Zoology and Entomology, Iowa State College, Ames, Iowa.
'32 Bailliere, Lawrence, Stoutland, Mo.
'36 Baird, John C., 218½ W. Walnut, Springfield, Mo.
'32 Bajkov, Dr. A. D., University of Manitoba, Winnipeg, Man., Canada.
'27 Baker, Clarence, 2 South Carroll St., Madison, Wis.
'36 Baker, Dr. Clinton L., % Southwestern, Memphis, Tenn.
'15 Balch, Howard K., 110 E. Seeboth St., Milwaukee, Wis.
'98 Ball, E. M., 107 Columbia St., East Falls Church, Va.
'37 Ball, Robert, Worthington, Ohio.
'23 Bangham, Dr. Ralph V., Wooster College, Wooster, Ohio.
'37 Banta, Emmitt W., Saratoga, Wyo.
'05 Barbour, Prof. Thomas, Museum of Comparative Zoology, Cambridge, Mass.
'37 Baumann, A. C., State Fish Farm No. 4, Russell's Point, Ohio.
'33 Bauman, Albert J., State Fish Farm No. 4, Russell's Point, Ohio.
'33 Beach, U. Sidney, Highland, Mich.
'36 Beard, Daniel B., 72 Pondfield Rd. W., Bronxville, N. Y.
'37 Bedard, Avila, Deputy Minister of Lands and Forests, Quebec, P. Q., Canada.
'37 Beckman, William, University Museums, Ann Arbor, Mich.
'36 Behney, W. H., Dept. of Zoology, University of Vermont, Burlington, Vt.
'34 Bell, Edward B., 84 Foster St., Lowell, Mass.
'33 Bell, Frank T., U. S. Bureau of Fisheries, Washington, D. C.
'37 Bennett, George W., Illinois Natural History Survey, Urbana, Ill.
'36 Bennington, Neville, 1114 Bever St., Wooster, Ohio.
'13 Berg, George F., 1702 E. 12th St., Indianapolis, Ind.
'37 Bickelhaupt, F. R., Lakefield Farm, Burton, Ohio.

'36 Biddle, Spencer, R. F. D. 1, Vancouver, Wash.
'36 Bielski, George J., State Fish Hatchery, Grayling, Mich.
'27 Birdseye, Clarence, General Seafoods Corporation, Gloucester, Mass.
'36 Bishop, Otto W., Alpena, Mich.
'34 Bishop, Sherman C., Dept. of Zoology, University of Rochester, Rochester, N. Y.
'24 Bitzer, Ralph, Montague, Mass.
'32 Blosz, John, Lake Park, Ga.
'37 Blue, Junior Sauber, 1150 Woodside Drive, Flint, Mich.
'36 Boesel, M. W., R. R. 2, Oxford, Ohio.
'32 Bogie, Robert R., 6740 Fourth Ave., Brooklyn, N. Y.
'37 Bosdash, Carl, State Fish Farm No. 9, R. D. 11, Defiance, Ohio.
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REPORT ON THE DISEASES OF BROOK TROUT

JOHN EDWARD DOE

Department of Conservation, Lansing, Michigan

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Item	Number of fish	Percentage of total	Average length in millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.05

12. *Capitals.* Capitalize words when used with a name or an identifying number or letter, or when referring to a particular State, Government, etc. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Boulder Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest.

Capitalize names of sections of the United States, or of any other country, as Middle West, but lower-case a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages) preceding Roman numerals, as Article I, Chapter II, Group VI, Age-Group II, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, in Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher orders.

13. *Abbreviations.* (a) Abbreviate the following:

Clock time, if connected with figures — 2:30 a.m.

Temperatures—F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc. — 75°, 75°F., 75° C.

''*Number,*'' when preceding figures — No. 125; otherwise spell out.

''*United States,*'' if preceding name of a department or a bureau or a vessel, etc. — U. S. Bureau of Fisheries, U. S. S. *Indiana.*

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5-September 2.

Measures and weight — 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage — 12 per cent, a percentage of 25.5.

14. *Numerals.* Spell out all *isolated* numbers which contain one or two digits, but use figures in a group of enumerations when any one number of that group contains more than two digits. Treat alike all numbers in a series of connected groups. For example: There were fifty trout. There were 50 trout, 120 bass, and 5 pike. There were fifty trout, twenty bass, and five pike. There were 50 trout and 20 bass in one can, and 50 trout and 120 bass in the other.

Figures must also be used after a colon in text if matter runs on, irrespective of the number of digits, as: The following shipment was made: 24 trout, 50 bass, and 2 carp.

Do not spell out numbers of three or more digits (except round numbers of approximations: ''estimated at five hundred''), and always use a comma in a number of four or more digits.

Use figures for all enumerations of dimension, weight, measure, distance (if fraction spell out, as one-half mile), clock time, money, percentage, degrees, proportion or ratios, age, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth). For example: $3.00 per 20 pounds; 5 feet 6 inches; about 10 miles; 6 acres; 4.30 p.m.; fish died in one hour and twenty minutes at 30 minutes past 4 o'clock; 25.5 per cent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938, the 20th day of March; 1937-38; 4:5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated.

Do not use two figures when two numbers appear together, as ten 12-room houses; twenty 6-inch trout.

Spell out figures beginning a sentence. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as ''Twenty to twenty-five trout.''

Spell out such expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout. Write 50-50, not ''fifty-fifty.''

15. *Use of hyphen.* Many compound words when used as nouns are not hyphenated but require use of the hyphen when used as adjectives. For example note the following sentences: ''This was *cold water.*'' ''Trout are *cold-water* fish.'' Check your manuscript carefully for use of hyphen. The words, ''subspecies,'' ''upstream'' and many other words originally of compound derivation are written without a hyphen.

Write ''largemouth'' and ''smallmouth'' as one word when referring to black bass.

III. SUBJECT MATTER

16. *Condense your paper* to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, direct, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. Papers which are too poorly written will be rejected. Do not expect your Editorial Committee to rewrite your manuscript.

17. *Be definite in references to species.* The scientific name, and wherever needed the complete common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "bass," "trout," "pike," and "pickerel" apply to any one of several species.

18. *Things to avoid.* The *words* "case," "instance," "show," "found," "gave," and "present" are overworked in manuscripts, the same word sometimes appearing several times in one paragraph.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used. The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: *This* was true in every *case*. *The mortality was high* in every *pond*.

19. *Abstract of paper.* Give a condensed summary or brief abstract at the beginning of your paper, if at all possible. This is especially desirable for all long papers.

Prepared by Publications Committee, John Van Oosten, Chairman.
February, 1937 (revised 1938).

PART I. SUBJECT INDEX

PART II. AUTHOR INDEX